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Derivation of I/M Benefits for Pre-1981 Light Duty Vehicles for Low Altitude, Non-California Areas

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16. ABSTRACT

This report presents the derivation of the Inspection/Maintenance (I/M) emission reduction benefits for pre-1981 model year vehicles (non-California low altitude) which were prepared for use in EPA's emission factor model, MOBILE2. MOBILE2 is a computer program which estimates fleet average emissions of the three regulated pollutants (hydrocarbons, carbon monoxide, and nitrous oxides) at various points in time under varying ambient and driving conditions. The effects of I/M are applied in MOBILE2 as percent reductions, or credits, to average emissions for various segments of the fleet. The Inspection and Maintenance benefits for 1981 and later model years were derived independently and are discussed in a separate report ("Derivation of I/M Benefits for Post-1980 Light Duty Vehicles for Low Altitude Non-California Areas", EPA-AA-IMS-81-2). NTIS # PB 81 194 102.

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1.0 INTRODUCTION

1.1 Purpose

This report presents the derivation of the Inspection/Maintenance (I/M) emission reduction benefits for pre-1981 model year vehicles (non-California low altitude) which were prepared for use in EPA's emission factor model, MOBILE2.* MOBILE2 is a computer program which estimates fleet average emissions of the three regulated pollutants (hydrocarbons, carbon monoxide, and nitrous oxides) at various points in time under varying ambient and driving conditions. The effects of I/M are applied in MOBILE2 as percent reductions, or credits, to average emissions for various segments of the fleet. The I/M benefits for 1981 and later model years were derived independently and are discussed in a separate report ("Derivation of I/M Benefits for Post-1980 Light Duty Vehicles for Low Altitude Non-California Areas", EPA-AA-IMS-81-2).

Although 40 CFR 51 Appendix N -- "Emission Reductions Achievable through Inspection and Maintenance of Light Duty Vehicles, Motorcycles, and Light and Heavy Duty Trucks" (the codification of EPA's first estimates of I/M credits) has been obsolete since the release of MOBILE1 (the predecessor to MOBILE2), many people still refer to whatever is EPA's current set of I/M credits and/or the methodology used to derive them as "Appendix N".

1.2 Methodological Improvements Over MOBILE1

The I/M credits described here and used in MOBILE2 are the product of a computerized simulation model as were those used in MOBILE1. As will be seen in the following, several significant improvements have been made in the model. A brief listing of the important improvements is given here.

The basic sample of test results from Emission Factor testing used in the simulation is much larger in MOBILE2. Over five thousand vehicles are included. MOBILE1 used results from less than eight hundred vehicles.

The most significant improvements come from the analysis of testing of vehicles involved in real-world I/M programs (Portland Study and New Jersey test lane data). The information gleaned from these data provide realistic evaluations of maintenance effects, deterioration following maintenance, the effect of mechanics' training, the effects of vehicle mileage accumulation, and the relationships among cutpoints, idle scores, and Federal Test Procedure (FTP) results.

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* The I/M credits documented in this report are not exactly those included in the original release of the MOBILE2 model. A coding error was made in the computer program listed in this report and as a result, the I/M credits originally included in the MOBILE2 model do not give the intended I/M credits, especially for HC emissions. The error occurred in subroutine DTRATN listed in pages 57 and 58 of this report. Variable PROJX(2) was inadvertantly coded PROJX instead of PROJX(P) within the loops. User Information Sheet #6 for MOBILE2 presents the corrected I/M credits for these vehicles.

There were also major improvements made in the derivation of credits for 1981 and later vehicles. These improvements are included in the above-mentioned technical report (EPA-AA-IMS-81-2).

1.3 Summary

Section 2.0 gives a brief discussion of the I/M credits for pre-1981 vehicles included in MOBILE2. A sample of the credits is presented. The credits are briefly compared with credits in MOBILE1.

Sections 3.1 and 3.2 indicate the data and types of models, respectively, which were under consideration in the development of the I/M simulation. Section 3.3 gives a verbal description of the general model structure and how it was built.

Section 4.0 presents the simulation model step-by-step with formulae and parameters given in their entirety.

The Appendix is a listing of the Fortran IV source code for the computer program which produced the credits.

2.0 RESULTS

2.1 Example Results for Archetypical Programs

The MOBILE2 computer program references I/M credits for pre-1981 model year cars on the basis of technology (Technology I refers to pre-1975 model years, Technology II refers to 1975-1980 model years), pollutant, program stringency, vehicle age at first inspection, benefit year (i.e., number of inspections), and presence or absence of mechanic training.* The general trends in the credits can be seen in Figures 1-8. The figures present all the credits used by MOBILE2 for pre-1981 model year vehicles for a 20% stringency I/M program. It can be seen that there is a generally increasing trend in credit with increasing benefit year for a given age of first inspection. Conversely, there is a generally increasing trend in credit with increasing age of first inspection for a given benefit year. However, this later trend is drastically less significant for Technology II. The incremental benefits due to mechanic training are small relative to other effects. For HC the increments are on the order of 0 to 2 percentage points and for CO they are in the range of 0 to 8 percentage points. Although not shown here, the effects of stringency are also small. Generally, for stringency ranging from 10% to 50%, the corresponding credits fluctuate by about ten percentage points of credit.

2.2 Comparison With Previous Estimates

Comparison between the I/M credits for pre-1981 model year vehicles in MOBILE1 and MOBILE2 is muddled by changes in the basic emission factors model and by a slightly different structure of the I/M credits within the program. For example, MOBILE2 estimates fleet average emissions as of January 1 of the evaluation year while MOBILE1 evaluated as of July 1. In terms of structure, MOBILE2 considers age of vehicle at implementation of the I/M program. In MOBILE1, vehicles received credits at first inspection based on one year of age regardless of actual age. This is inaccurate since the older a vehicle is at first inspection, the greater is the benefit at the first few inspections.

A general comparison of the two sets of credits can be made based on the effects on the fleet emission levels. Figures 9 and 10 present a comparison of percent reductions in the pre-1981 model year fleet average emission estimates for January 1, 1988 from MOBILE1 and MOBILE2 for I/M programs beginning January 1, 1983. Since MOBILE1 evaluates for July 1 dates and assumes I/M programs start July 1, interpolation was required for comparison with MOBILE2. Although this is only one set of examples, the conclusions to be drawn are generally applicable. For HC (Figure 9) there is very little effect of mechanic training from MOBILE2. The reductions for both with and without mechanic training from MOBILE2 are less than those for MOBILE1 with no mechanic training at all stringencies. For CO (Figure 10), although there is a greater effect due to mechanic training in MOBILE2 than for HC, both cases fall between the reductions observed in MOBILE1 for the with and without-mechanic training cases.

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* The I/M credits documented in this report are not exactly those included in the original release of the MOBILE2 model. Further explanation is presented in the footnote on page 3 of this report.

3.0 BACKGROUND AND GENERAL DESCRIPTION OF SIMULATION MODEL

3.1 Data Availability

3.1.1 Operating I/M Programs

Although there are a few operating I/M programs, in those where data is recorded from testing there is generally only idle or other short test data available.

3.1.2 Portland Study

In order to obtain the necessary data from an actual I/M program, EPA has been conducting tests in Portland, Oregon through a contractor, Hamilton Test Systems, since September, 1977. As input for the modeling of the I/M process EPA has four pertinent data sets from the Portland Study. The first data set, Element I, is a group of as-received tests on about 2200 1975-77 model year cars from Portland. Two data sets come from Element II. About 200 cars each from model years 1972-74 (Technology I) and model years 1975-77 (Technology II) were tested five or six times using the FTP: as-received, following maintenance if required by the Portland I/M program, and four times at quarterly intervals over the year following the initial test. The fourth data set, Element III, consists of testing similar to that done in Element II on about 300 1975-77 model year cars.

3.1.3 Emission Factors

From Emission Factors testing, EPA's ongoing in-use surveillance program, there are 2678 Technology I and 2456 Technology II cars from the FY71 program through the FY79 program. These are tests from low-altitude, non-California, non-Phoenix (where I/M was operating) sites. All tests are as-received.

3.2 Alternate Models

Before arriving at the current model, several alternatives were considered. EPA began by looking at the previous model to determine whether minor modifications would suffice. EPA then looked at two more general classes of models: stochastic models and all means models. Each of these are discussed below. It will be apparent that the current model is a hybrid of the three.

3.2.1 Previous Model

The previous model was developed before much data was available relative to I/M. Deterioration was predicted for individual vehicles based on the relationship between their actual test measurements and MOBILE1 predictions. The resultant fleetwide deterioration is parallel to the MOBILE1 without-I/M deterioration. Reductions were determined for individual cars based on single pollutant regression equations between idle and FTP. Cars designated as failing only one pollutant were simulated as having maintenance effects only on that pollutant in the absence of mechanic training. With mechanic training

every failed car was assumed to be emitting at its new car standard after maintenance.

3.2.2 Stochastic Models

Classical stochastic models were considered. The general approach would be to determine predictive relationships among variables of interest. The stochastic element would then enter as individual vehicles' random deviations from the strict relationships. However, upon examination of available data, EPA determined that the variance-covariance structures among the variables of interest were too weak to support this approach. In other words, the data showed that the relationships among the variables on individual vehicles are too erratic to provide meaningful individual car predictions.

3.2.3 All Means Models

Given the problems caused by the erratic behavior of individual vehicles as described above, the next logical approach is an all means model. This involves the same basic development as the stochastic models (i.e., finding predictive relationships among the variables of interest), but with the variables entering as means from a group of vehicles. The variability problem is reduced. The stochastic element could be minimized or discarded completely. However, problems arose due to lack of flexibility in determining the results of inspection. It was not possible to predict group failure rates in a satisfactory manner without looking at the individual car deterioration and the relationships between idle and FTP.

3.3 General Model Description

3.3.1 Calendar Year - Model Year Relationship

MOBILE2 requires I/M credits in the form of individual percent reductions to each model year's emission factor as of January 1 of a given calendar year. The credit is further specificed by start date of the I/M program, program stringency, presence or absence of mechanic's training, and pollutant (HC or CO). MOBILE2 applies the I/M credit to each model year's emission factor, then combines the model years to form a composite fleet emission factor.

In order to derive the credits, the simulation used the entire input sample for a given technology to produce a twenty-year emissions history for a given age of first inspection and stringency. The twenty-year histories were used as described below in Section 4.8 to determine model year credits which are referenced in MOBILE2 by age of first inspection and benefit year. MOBILE2 uses calendar year, model year, and start date of the I/M program to determine age of first inspection and benefit year for a given model year at a given calendar year.

3.3.2 Vehicle Groupings

As discussed in Section 3.2, the production of the twenty-year emissions histories was accomplished by a hybrid model which contains aspects of the previous model, stochastic models, and all means models. At the time of inspection, the simulation fleet was considered on an individual vehicle

basis. After maintenance emissions were determined by failure group (failing HC, CO, or both). Deterioration was predicted for the mean of the entire fleet.

3.3.3 Initial Adjustment of Sample

The best sample of vehicle test data available comes from EPA's Emission Factors Programs from Fiscal Years 1971, 1972, 1973, 1974, 1975, 1977, and 1979. Testing under these programs spanned the calendar years 1971 through 1980. To begin each twenty-year fleet emissions history, a group of vehicles of the same chronological age is required. Rather than search the sample for vehicles of the required age at time of testing which would yield small or null samples in many cases, the entire sample of vehicles of the required technology was used. The sample was adjusted to simulate a sample of vehicles at the required age of first inspection. Each stratum from a stratification based on model year and calendar year of the Emission Factor testing was individually adjusted to obtain a group of vehicles with mean odometer reading and FTP emissions as predicted by MOBILE2 for the required age of first inspection. The resulting individually adjusted sample of vehicles then received adjustments to their idle scores to reflect the adjustments to mileage and FTP emissions. The idle adjustments were based on adjusted mileage and FTP emissions plus engine size (CID) and actual idle measurements. The simulation of the twenty-year emissions history then began with the sample of vehicles adjusted to the chronological age when the first inspection would take place. The history prior to this point is simply that predicted by MOBILE2 in the absence of an I/M program.

3.3.4 Simulation Cycle

At the first inspection of the twenty-year emissions history, the adjusted idle scores from the sample were used to determine idle emission cutpoints which yield the specified failure (stringency) rate. These cutpoints were retained through the remainder of the twenty-year emissions history. Using these cutpoints each vehicle was designated as passed, HC failure, CO failure, or a failure on both pollutants. After maintenance mean emission levels were predicted for each failure group based on mileage, cutpoints, failure mode, and presence or absence of mechanic's training. The passed vehicles retained emission levels from before inspection. The after maintenance emisson levels were recombined to form fleet emission levels. Deterioration of the fleet mean emission levels up to the next inspection point was predicted based on after maintenance fleet mean emissions levels, mileage, and the MOBILE2 prediction of non-I/M fleet emissions. At the next inspection, each vehicle's mileage and FTP emissions were adjusted based on the new fleet means. The idle scores for each vehicle were predicted based on CID and the new mileage and FTP emissions. The cycle of inspection, emission reduction, and deterioration was then repeated until the fleet completed the twenty-year history.

4.0 DETAILED DESCRIPTION OF MODEL

This section presents a detailed description of the steps followed in the simulation. As discussed in Section 3, the model is a hybrid containing aspects of the previous deterministic model (MOBILE1), stochastic models, and all means models. The sample input consisted of test results and information on individual vehicles. The individual vehicle variables were initially adjusted to be consistent with MOBILE2 predictions for the means. Artificial deviations were added to simulate the stochastic nature of the relationship among idle scores and other variables. Individual vehicles' idle scores were used in the inspection process. The effects of maintenance and deterioration were based on predictions of means. The results from the mean predictions were translated back to the individual vehicle variables for the purpose of subsequent inspection simulations.

4.1 Vehicle Sample

The simulation started with a sample from Emission Factors data. These are data from the same cars which are used in determining the basic emission factor equations used in MOBILE2. The sample has 2456 Technology II cars and 2678 Technology I cars. For each car the sample contains the vector of observations:

$$\underline{x}'_i = (x_{i1}, x_{i2}, x_{i3}, x_{i4}, x_{i5}, x_{i6}, x_{i7}, x_{i8});\ i = 1,\ldots,n;$$

where x_{i1} = odometer,
x_{i2} = FTP HC,
x_{i3} = FTP CO,
x_{i4} = idle HC,
x_{i5} = idle CO,
x_{i6} = CID,
x_{i7} = model year, and
x_{i8} = EF Program year.

4.2 Adjustment To MOBILE2 Predictions

At the first inspection year MOBILE2 predicts the without-I/M mean odometer, FTP HC and FTP CO, say x_{01}, x_{02}, x_{03}. To achieve these means in the simulation sample, the simulation adjusted the sample in the following manner:

Let $x^*_{i1} = x_{i1}\ (x_{01}/\bar{x}_1)$ where, $\bar{x}_1$ is the mean mileage of those vehicles in the sample which have a common model year-program year combination.

Then $\bar{x}^*_1 = x_{01}$, i.e., the model year-program year adjusted mean is equal to the MOBILE2 predicted mean. In a similar manner, individual vehicle FTP emissions were adjusted by

$x^*_{i2} = x_{i2}(x_{02}/\bar{x}_2)$ and $x^*_{i3} = x_{i3}(x_{03}/\bar{x}_3)$ where $\bar{x}_2$ and $\bar{x}_3$

are the FTP HC and CO means (before adjustment), respectively, averaged within the program year-model year groups. The program year-model year designations were used to maintain appropriate mileage accumulation rates.

There is an implicit assumption that the vehicles are being adjusted to the same chronological age within about two or three months. For a subsample of the vehicles, build date was available. In conjunction with test date, build date allows for slightly increased accuracy in age determination relative to the program year and model year information. However, when the two methods of adjustment were compared, no substantial differences in mileage and FTP emissions distributions were detected.

4.3 Calculation of Initial Idle Values

Regression equations of the form

$$X_{ij} = b_{jo} + b_{j1}X_{i1} + b_{j2}X_{i2} + b_{j3}X_{i3} + b_{j6}X_{i6};\ j=4,5;\ i = 1, \ldots, n$$

have been developed* to predict idle scores from the individual vehicle engine sizes and adjusted mileages and FTP scores. The regression coefficients are given in Table 1. In order to calculate idle values for the sample after adjustment of mileages and FTP scores to MOBILE2 predictions, the first estimate is given by:

$$\hat{x}_{ij} = b_{jo} + b_{j1}x_{i1} + b_{j2}x_{i2} + b_{j3}x_{i3} + b_{j6}x_{i6};\ j=4,5;$$

and, if $\hat{x}_{i4} < 0$, let $\hat{x}_{i4} = 1.$; if $\hat{x}_{i5} < 0$, let $\hat{x}_{i5} = .1$. Then, let

$r_{ij} = x_{ij}/\hat{x}_{ij}$; i=1,...n; j=4,5. Using the individual deteriorated vectors,

$$\hat{x}^*_{ij} = b_{jo} + b_{j1}x^*_{i1} + b_{j2}x^*_{i2} + b_{j3}x^*_{i3} + b_{j6}x^*_{i6};\ j=4,5.$$

If $\hat{x}^*_{i4} < 0$, let $\hat{x}^*_{i4} = 1.$; if $\hat{x}^*_{i5} < 0$, let $\hat{x}^*_{i5} = 1.$

Finally, let $x^*_{ij} = \hat{x}^*_{ij}r_{ij}$; i = 1,...,n; j = 4,5. Then x^*_{i4} and x^*_{i5} are assumed to be the idle HC and CO values respectively for the cars at first inspection. They have been adjusted to account for deterioration and have a synthetic deviation from a perfect regression based on the actual measured idle scores for each car.

4.4 Inspection

At the point of first inspection, the derived idle scores were used to determine idle cutpoints. This was done in a manner such that the desired failure rate was obtained concurrently with one of the the following conditions**:

---

* The data base used to derive the regression equations consisted of as-received test results from 2552 Technology I cars and 2454 Technology II cars from Emission Factors data.

** These conditions are thought by EPA to result in a reasonable balance of HC and CO failures. Some such conditions are necessary to establish cutpoints, since a desired failure rate alone does not determine them uniquely.

1) if the CO cutpoint is greater than or equal to 3.0, then the HC cutpoint (in PPM) is 100 times the CO cutpoint (in percent); or,

2) if the CO cutpoint is less than 3.0, then the HC cutpoint is 150 plus fifty times the CO cutpoint.

The derived idle scores were then compared with the cutpoints to determine which cars passed and failed. Since the maintenance effects were to be based on predictions for means by failure mode (i.e., whether HC or CO or both were failed), the individual vehicles were assigned a failure mode at inspection. The respective failure rates and mean FTP emissions were calculated by failure mode, i.e., f_{ij} and FTP_{ijk}, where

i = 1: pass HC,
    2: fail HC;

j = 1: pass CO,
    2: fail CO; and

k = 2: FTP HC,
    3: FTP CO.

4.5 Reductions Due to Maintenance

Overview

The mean FTP emissions for failed cars after maintenance for pollutant k (k = 2:HC, 3:CO) and failure group ij (i = 1:HC pass, 2:HC fail; j = 1:CO pass, 2:CO fail) are given for each Technology (I and II) by

$$FTP_{ijk} = d_{ijko} + d_{ijk1}M_{ij} + d_{ijk4}\ IHC_C + d_{ijk5}\ ICO_C$$

where M_{ij} is mean mileage for the (ij) failure group; IHC_C and ICO_C are the idle HC and idle CO cutpoints respectively; and there is no mechanic training. The passed cars (i=1, j=1) retained the mean FTP levels (FTP_{112} and FTP_{113}) observed at inspection.

The mean FTP emissions for the entire fleet (all four failure groups combined) after maintenance for pollutant k were estimated by:

$$\sum_{i=1}^{2}\ \sum_{j=1}^{2} f_{ij}\ FTP_{ijk} \Big/ \sum_{i=1}^{2}\ \sum_{j=1}^{2} f_{ij},$$

where f_{ij} is the proportion of the fleet in each of the failure groups.

Detailed Derivation

The d_{ijk}'s were derived in a four step process:

1) First, the a_k's were estimated by regression in:

$$x_{mk} = a_{ko} + a_{k1}x_{m1} + a_{k4}\,IHC_{Cm} + a_{k5}\,ICO_{Cm};\ m = 1,\ldots,n;\ k = 4,5;$$

where IHC_{Cm} is the idle HC cutpoint imposed on the mth vehicle by an I/M program at reinspection following repair and ICO_{Cm} is the idle CO cutpoint applied to the mth vehicle. (Not all vehicles in the regression sample have the same cutpoints because the sample comes from two I/M programs, and one of these imposes cutpoints which vary by vehicle make and model.) x_{mk} for k=4 and 5 are the idle HC and CO measurements, respectively, for the mth vehicle at reinspection. x_{m1} is the odometer reading for the mth vehicle. The estimates for these equations are given in Table 2. The sample used in estimating the a_k's consists of after maintenance official reinspection tests from the Portland and New Jersey I/M programs.* The intention was to quantify empirically the average margins by which idle emissions after maintenance fall below the cutpoints in an I/M program. Such margins are possible because I/M cutpoints are always set well above the idle emissions of well tuned vehicles. Margins are expected since repair mechanics will tend to reduce idle emissions well below the program cutpoints to provide a safety margin to guard against failure at reinspection.

2) Next, the c_{ijk}'s were estimated by regression in

$$x_{mk} = c_{ijko} + c_{ijk1}x_{m1} + c_{ijk4}x_{m4} + c_{ijk5}x_{m5};\ m = 1,\ldots,n;\ k = 2,3;$$

from Portland after maintenance and first quarter tests on failed cars.** This equation predicts individual FTP levels after maintenance from individual idle levels and mileage. As above, (ij) refers to failure mode. x_{m1}, x_{m2}, and x_{m3} are mileage, FTP HC, and FTP CO, respectively. x_{m4} and x_{m5} are the idle emissions as above. The coefficients are given in Table 3.

3) A first iteration estimate for after maintenance average FTP emissions as a function of cutpoints for each failure group putting together (1) and (2) above is:

$$g_{ijk}(M_{ij},\ IHC_C,\ ICO_C) = c_{ijko} + c_{ijk1}M_{ij}$$
$$+ c_{ijk4}\,(a_{40} + a_{41}M_{ij} + a_{44}\,IHC_C + a_{45}\,ICO_C)$$
$$+ c_{ijk5}\,(a_{50} + a_{51}M_{ij} + a_{54}\,IHC_C + a_{55}\,ICO_C).$$

---

* From Elements II and III of the Portland Study, 320 tests were used. From New Jersey, 1333 tests recorded in 1975-1979 were used.

** For Technology I, 159 tests from Element II were used. For Technology II, 386 tests from Elements II and III were used.

4) To insure that the prediction at the mean of the Portland observations is correct, the following relationship must hold:

$$FTP_{ijkL} = g_{ijk}(M_{ijL}, IHC_{CL}, ICO_{CL})FTP_{ijkP} / g_{ijk}(M_{ijP}, IHC_{CP}, ICO_{CP})$$

where P refers to Portland and L refers to local, i.e., the program under consideration.

To achieve this relationship, letting $k_{ijk} = FTP_{ijkP}/g_{ijk}(M_{ijP}, IHC_{CP}, ICO_{CP})$

and reassembling the above,

$$d_{ijko} = k_{ijk}(c_{ijko} + c_{ijk4}\, a_{40} + c_{ijk5}\, a_{50}),$$

$$d_{ijk1} = k_{ijk}(c_{ijk1} + c_{ijk4}\, a_{41} + c_{ijk5}\, a_{51}),$$

$$d_{ijk4} = k_{ijk}(c_{ijk4}\, a_{44} + c_{ijk5}\, a_{54}), \text{ and}$$

$$d_{ijk5} = k_{ijk}(c_{ijk4}\, a_{45} + c_{ijk5}\, a_{55}).$$

As seen in Table 4, the k_{ijk} are reasonably close to one (1) indicating consistency in the model. The d_{ijkm}'s are presented in Table 5. The simulation checked whether

$x_{mk} = a_{k0} + a_{k1}\, x_{m1} + a_{k4}\, IHC_{Cm} + a_{k5}\, ICO_{Cm}$; k = 4,5 yields

$x_{m4} > IHC_{Cm}$, or $x_{m5} > ICO_{Cm}$.

Although unlikely, due to the statistical nature of the prediction this may occur implying the car is above the cutpoints after maintenance. If it did, the simulation assigned $x_{m4} = IHC_{Cm}$, or $x_{m5} = ICO_{Cm}$, respectively.

Then,

$$FTP_{ijk} = k_{ijk}[c_{ijko} + c_{ijk1}\, M_{ij} + c_{ijk4}\, IHC_{CL} + c_{ijk5}(a_{50} + a_{51}\, M_{ij} + a_{54}\, IHC_{CL} + a_{55}\, ICO_{CL})],$$

or,

$$FTP_{ijk} = k_{ijk}[c_{ijko} + c_{ijk1}\, M_{ij} + c_{ijk4}(a_{40} + a_{41}\, M_{ij} + a_{44}\, IHC_{CL} + a_{45}\, ICO_{CL}) + c_{ijk5}\, ICO_{CL}],$$

if the after maintenance idle was predicted above the cutpoint.

With mechanic training, after maintenance FTP means were predicted by:

$$FTP'_{ijk}(M_{ij}) = d'_{ijko} + d_{ijk1}\, M_{ij}$$

where d_{ijkl} is the same as in the without mechanic training case. The d'_{ijko}, were derived by letting

$$\frac{\text{mean FTP}_T}{\text{mean FTP}_U} = \frac{FTP'_{ijk}(M_T)}{FTP_{ijk}(M_U,\ IHC_{CU},\ ICO_{CU})}$$

$$= \frac{d'_{ijko} + d_{ijkl} M_T}{d_{ijko} + d_{ijkl}\ M_U + d_{ijk4}\ IHC_{CU} + d_{ijk5}\ ICO_{CU}}$$

and solving for d'_{ijk}. T and U refer to (Portland Study) mechanic training study trained and untrained, respectively. Thus, the ratio of predicted trained to untrained is the same as the observed ratio at the given levels of the parameters.

If $d'_{ijko} > d_{ijko} + d_{ijk4}\ IHC_{CU} + d_{ijk5}\ ICO_{CU}$,

d'_{ijko} was set equal to the right-hand side of the above inequality. There was a further restriction that $FTP'_{ijk} \leq FTP_{ijk}$. Both of the restrictions insure that after maintenance FTP levels are always predicted the same or lower with training than without. Due to the small sample size in the Portland mechanic training study, the derivation of d'_{ko} was carried out without stratification by failure mode for the Technology I vehicles. The estimates for d's for mechanic training are presented in Table 6.

The mean FTP emissions for the entire fleet (all four failure groups combined) after maintenance for each pollutant then is estimated by the equation presented in the overview in Section 4.5.

4.6 Deterioration

Before the first inspection, the fleet's mean FTP emissions deteriorate according to equations given by MOBILE2.

Following the first inspection we assume that the fleet would be back at the MOBILE2 FTP line m_k (k = 2: FTP HC, 3: FTP CO) miles after the inspection. The path of deterioration is then a straight line between the after maintenance mean and the point on the MOBILE2 line m_k miles after the first inspection. (See Figure 11.) The mileage intervals required to return to MOBILE2 lines are given in Table 7. The mileage intervals were predicted based on the fleetwide means from the total Portland fleets in Elements II and III of the Portland Study.

After each subsequent annual inspection-and-repair point, fleet deterioration again follows the path from the after maintenance level to the point m_k miles later on the MOBILE2 line.

If the deterioration path defined by this rule would reach the MOBILE2 line before the next annual inspection is due (as can occur only for Technology I vehicles with low age at first inspection), a different path is taken instead. This other path is a straight line connecting the after maintenance point and the point on the MOBILE2 line at the next inspection point.

4.7 Iterations

At the mth inspection, x^m_{o1} (mean mileage) is given by MOBILE2 and x^m_{o2} and x^m_{o3} (mean FTP emissions) are given by deterioration following the (m-1)th inspection. The sample mileages and FTP emissions were adjusted in the following way:

$$x^m_{ij} = \hat{x}^m_{ij}(x^m_{oj}/\bar{x}^*_j);\ j = 1,2,3.$$

Initial estimates for individual idle values were obtained by

$$\hat{x}^m_{ij} = b'_{jo} + b'_{j1}x^m_{i1} + b'_{j2}x^m_{i2} + b'_{j3}x^m_{i3} + b'_{j6}\,x^m_{i6};$$

$i = 1,\ldots,n;\ j = 4,5.$ If $\hat{x}^m_{i4} < 0$, let $\hat{x}^m_{i4} = 1$; if $\hat{x}^m_{i5} < 0$, let $\hat{x}^m_{i5} = .1$

These regression coefficients, $b'_{jo},\ldots, b'_{j6}$ were derived from Elements I and II of the Portland Study using tests after at least one inspection has occurred and less than a year has passed since the last inspection. This sample included 63 Technology I vehicles and 372 Technology II vehicles. The coefficient estimates are given in Table 1. Synthetic variability around the regressions was obtained by letting

$$x^m_{ij} = \hat{x}^m_{ij}\, r_{ij};\ i = 1,\ldots,n;\ j = 4, 5.$$

Using the cutpoints determined at the first inspection, inspection and deterioration were carried out as above and the simulation continued with the next iteration.

4.8 January 1st Percent Reductions

The twenty-year emissions histories for a given Technology, stringency, pollutant, and presence or absence of mechanic training were produced for ages of first inspection from one to nineteen. The emissions prior to the first inspection were those predicted by MOBILE2 for the non-I/M fleet. I/M reductions contained in MOBILE2 are the percent reductions for each model year from the non-I/M fleet to the I/M fleet on January 1 of the evaluation year. The I/M simulation program needed to combine portions of the twenty-year emissions histories to produce I/M model year average emissions as of January 1. A detailed description of this procedure follows.

Vehicle sales were assumed to be evenly distributed over the model year which runs from October of the model year minus one through September of the model year. In this discussion it will be conveninent to refer to new vehicles sold October 1 through December 31 as "first-quarter vehicles" and those sold January 1 through September 30 as "last-three-quarters vehicles". To facilitate this dicussion the following new terminology is defined:

INT	=	zero mile emission rate as predicted by MOBILE2
AGEIST	=	age at which first-quarter vehicles are first inspected
E(BY)	=	mean FTP emissions for model year fleet on January 1 following BYth inspection of first-quarter vehicles
TFB(BY)	=	mean FTP emissions immediately before BYth inspection
TFA(BY)	=	mean FTP emissions immediately after BYth inspection

LFB(BY) = mean FTP emissions immediately before BYth inspection for cars having first inspection at age AGEIST-1

LFA(BY) = mean FTP emissions immediately after BYth inspection for cars having first inspection at age AGEIST-1

The last four of these values come from the simulated twenty-year emissions history.

AGEIST = 1

Figure 12 indicates the pattern of emissions for the first-quarter and last-three-quarters vehicles when the I/M program is in effect before the first quarter vehicles reach their first anniversary of sales. On January 1 of calendar year MY+1 the first-quarter vehicles are an average of one and one-half months past their first inspection. The last-three-quarters vehicles are an average seven and one-half months before their first inspection. The January 1 I/M fleet mean emission levels for AGEIST=1 were calculated from the twenty-year emissions histories as follows:

$$E(1) = .25\,[TFA(1)+1.5(TFB(2)-TFA(1))/12] + .75\,[INT+7.5(TFB(1)-INT)/12],$$

and, for BY=2 to 19,

$$E(BY) = .25\,[TFA(BY)+1.5(TFB(BY+1)-TFA(BY))/12] + .75\,[TFA(BY-1)+7.5(TFB(BY)-TFA(BY-1))/12].$$

AGEIST = 2 to 19

Figure 13 indicates the pattern of emissions for the first-quarter and last-three-quarters vehicles when the I/M program starts after the first-quarter vehicles have passed the first anniversary of their original sale but before the last-three-quarters vehicles have passed their first anniversary. This case corresponds to AGEIST=2. The first year for which model year MY would show reductions due to I/M on January 1 would be MY+2. On that day first-quarter vehicles would be an average of one and one-half months passed their first inspection. The last-three-quarters vehicles would be an average of seven and one-half months passed their first inspection. Note that the age at first inspection for last-three-quarters vehicles is one less than for first-quarter vehicles. This pattern continues through the I/M history of all vehicles with AGEIST greater than one. The January 1 I/M fleet mean emission levels for model years with AGEIST greater than one were calculated from the twenty-year emissions histories for BY=1 to 20-AGEIST as follows:

$$E(BY) = .25\,[TFA(BY)+1.5(TFB(BY+1)-TFA(BY))/12] + .75\,[LFA(BY)+7.5(LFB(BY+1)-LFA(BY))/12]$$

Table 1
Regression Coefficients for Predicting Idle Emissions

Technology I	Intercept	Miles/10K	FTP HC	FTP CO	CID
Initial Idle HC	140.37	6.17	76.22	-1.18	-.30
Initial Idle CO	2.3937	.0120	.0534	.0472	-.0055
Subsequent Idle HC	-131.35	24.94	28.08	11.20	-1.00
Subsequent Idle CO	.6558	-.0206	.0382	.0642	-.0051
Technology II					
Initial Idle HC	11.13	-.165	102.23	-.32	.03
Initial Idle CO	.4258	-.0118	.0843	.0608	-.0017
Subsequent Idle HC	-.1164	-2.18	59.22	1.31	.12
Subsequent Idle CO	.4796	-.0672	.0398	.0655	-.0011

Table 2
Estimated a_{kk}' for Predicting After Maintenance Idle Levels

Technology I (Pre-1975 model years)

	Idle HC		Idle CO
a_{40}	59.396	a_{50}	-.65963
a_{41}	8.2111	a_{51}	.06151
a_{44}	0.0	a_{54}	0.0
a_{45}	12.106	a_{55}	.46582

Technology II (1975-79 model years)

	Idle HC		Idle CO
a_{40}	27.814	a_{50}	-.27163
a_{41}	4.6612	a_{51}	0.0
a_{44}	0.0	a_{54}	0.0
a_{45}	18.517	a_{55}	.39050

Table 3

Estimated c_{ijkl}'s for Predicting After Maintenance FTP Levels

Technology I (Pre-1975 model years)

FTP HC		FTP CO	
C_{2120}	2.8093	C_{2120}	41.933
C_{2121}	0.0	C_{2121}	0.0
C_{2124}	0.0	C_{2124}	0.0
C_{2125}	0.0	C_{2125}	0.0
C_{1220}	2.4490	C_{1220}	23.007
C_{1221}	-.20922	C_{1221}	1.3794
C_{1224}	.012067	C_{1224}	0.0
C_{1225}	0.0	C_{1225}	6.6541
C_{2220}	1.0398	C_{2220}	43.096
C_{2221}	.21054	C_{2221}	0.0
C_{2224}	.004185	C_{2224}	0.0
C_{2225}	0.0	C_{2225}	0.0

Technology II (1975-79 model years)

FTP HC		FTP CO	
C_{2120}	1.0906	C_{2130}	16.275
C_{2121}	0.0	C_{2131}	0.0
C_{2124}	.00464	C_{2134}	0.0
C_{2125}	0.0	C_{2135}	28.224
C_{1220}	.80638	C_{1230}	14.391
C_{1221}	.21934	C_{1231}	1.3610
C_{1224}	0.0	C_{1234}	0.0
C_{1225}	0.0	C_{1235}	-.021437
C_{2220}	1.0855	C_{2230}	16.379
C_{2221}	.14956	C_{2231}	1.7465
C_{2224}	.0014085	C_{2234}	0.0
C_{2225}	0.0	C_{2235}	9.6023

Table 4

Estimated k_{ijk}'s for Predicting After Maintenance FTP Levels

Technology I (Pre-1975 model years)

FTP HC		FTP CO	
k_{212}	.96569	k_{213}	.65245
k_{122}	1.0647	k_{123}	.99755
k_{222}	1.1575	k_{223}	1.0489

Technology II (1975-79 model years)

FTP HC		FTP CO	
k_{212}	1.1237	k_{213}	1.0771
k_{122}	.92395	k_{123}	.91849
k_{222}	1.0792	k_{223}	1.0095

Table 5

Estimated d_{ijkm}'s for Predicting After Maintenance FTP Levels

Technology I (Pre-1975 model years)

FTP HC		FTP CO	
d_{2120}	2.7129	d_{2130}	27.359
d_{2121}	0.0	d_{2131}	0.0
d_{2125}	0.0	d_{2135}	0.0
d_{1220}	3.3706	d_{1230}	18.572
d_{1221}	-.11727	d_{1231}	1.7843
d_{1225}	.15554	d_{1235}	3.0920
d_{2220}	1.4913	d_{2230}	45.203
d_{2221}	.28348	d_{2231}	0.0
d_{2225}	.05864	d_{2235}	0.0

Technology II (1975-79 model years)

FTP HC		FTP CO	
d_{2120}	1.3705	d_{2130}	9.2720
d_{2121}	.02430	d_{2131}	0.0
d_{2125}	.09655	d_{2135}	11.871
d_{1220}	.74506	d_{1230}	13.223
d_{1221}	.20266	d_{1231}	1.2501
d_{1225}	0.0	d_{1235}	-.00769
d_{2220}	1.2137	d_{2230}	13.902
d_{2221}	.16849	d_{2231}	1.7631
d_{2225}	.02815	d_{2235}	3.7853

Table 6

Estimated d'_{ijko}'s for Predicting After Maintenance FTP Levels

Technology I (Pre-1975 model years)*

FTP HC		FTP CO	
d'_{20}	3.7504	d'_{30}	37.49

Technology II (1975-79 model years)

FTP HC		FTP CO	
d'_{2120}	1.4671	d'_{2130}	11.358
d'_{1220}	.32275	d'_{1230}	5.1816
d'_{2220}	1.2418	d'_{2230}	17.687

* As noted above, failure mode stratifications (ij) was dropped for Technology I.

Table 7

Predicted Mileage Intervals (m_k) for Fleet Mean FTP Emissions to Reach Non-I/M Levels Following Maintenance

	HC	CO
Technology I (Pre-1975 Model Years)	7,400	40,000
Technology II (1975-79 Model Years)	27,000	57,200

Figure 1

HC Credits for Technology I Vehicles
for a 20% Stringency I/M Program With No Mechanic Training

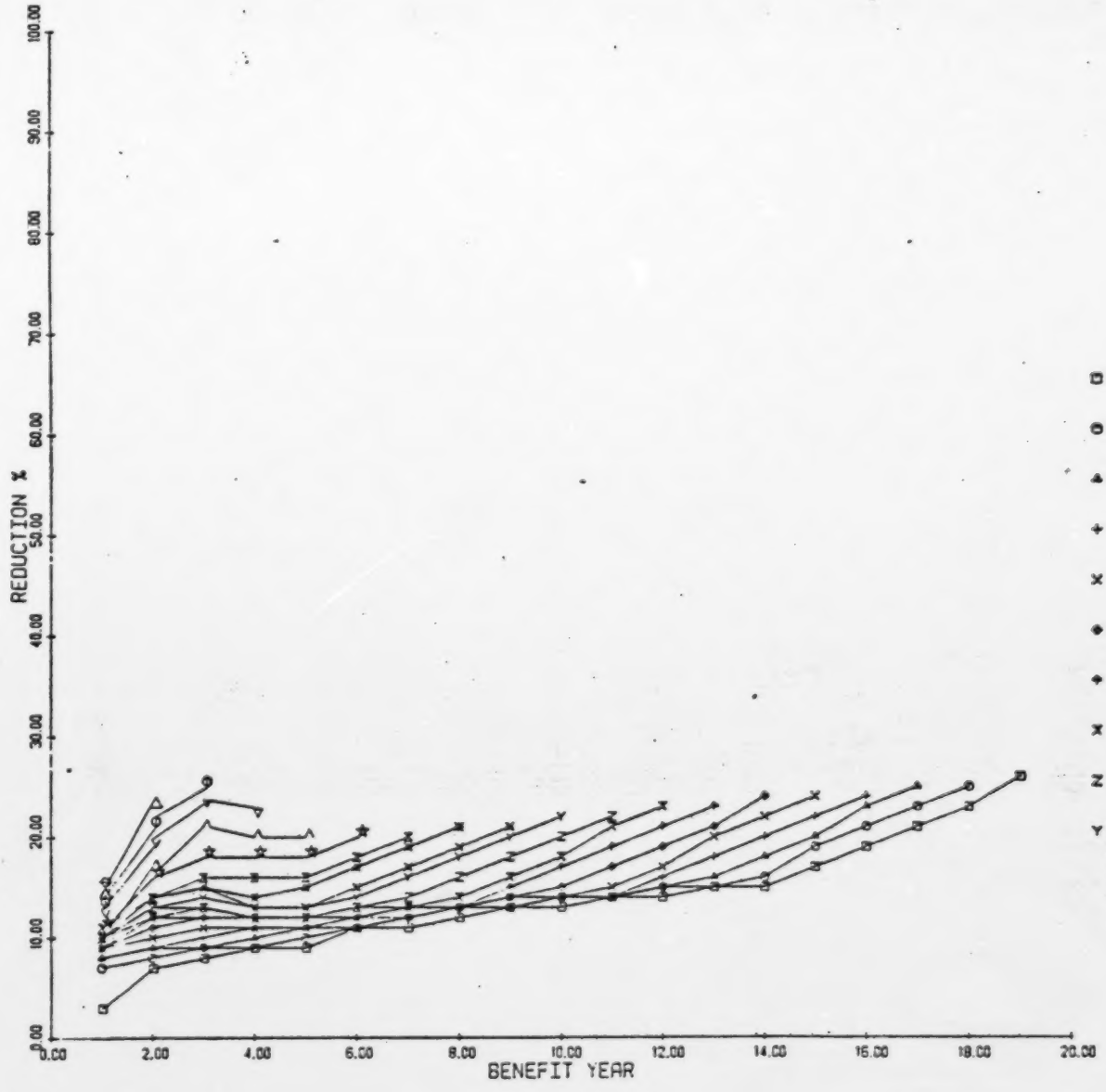


Figure 2

CO Credits for Technology I Vehicles
for a 20% Stringency I/M Program With No Mechanic Training

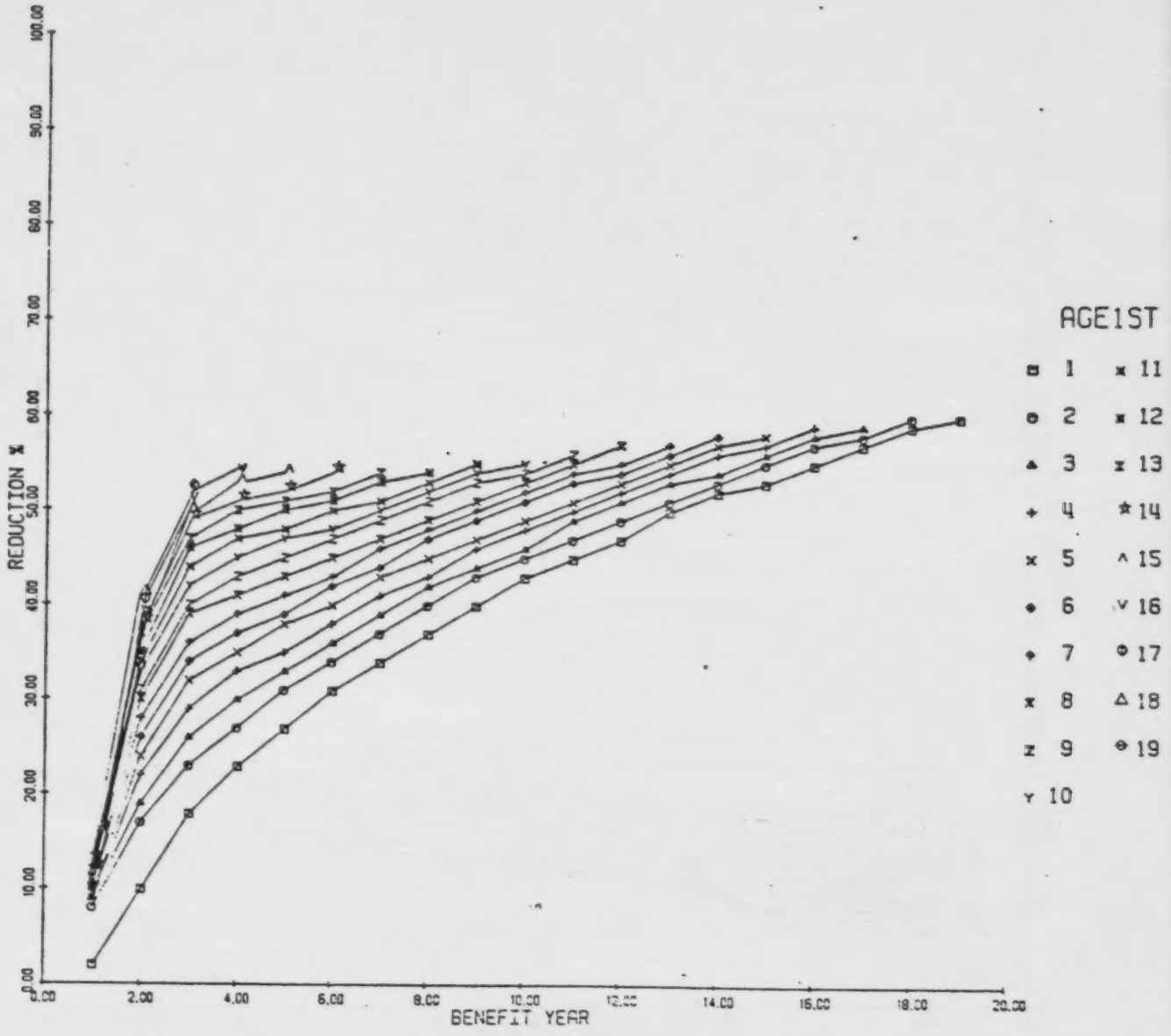


Figure 3

HC Credits for Technology I Vehicles
for a 20% Stringency I/M Program With Mechanic Training

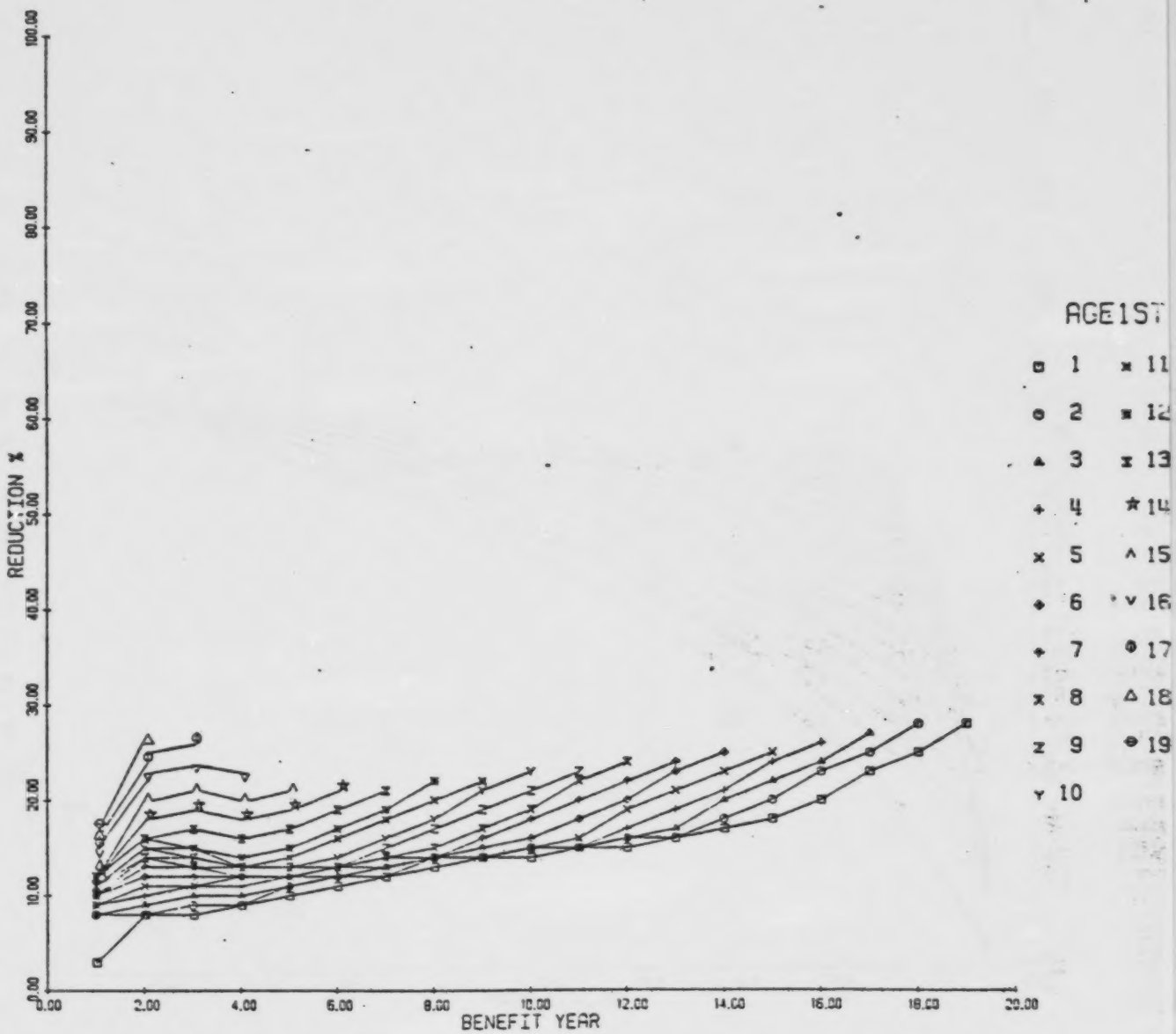


Figure 4

CO Credits for Technology I Vehicles
for a 20% Stringency I/M Program With Mechanic Training

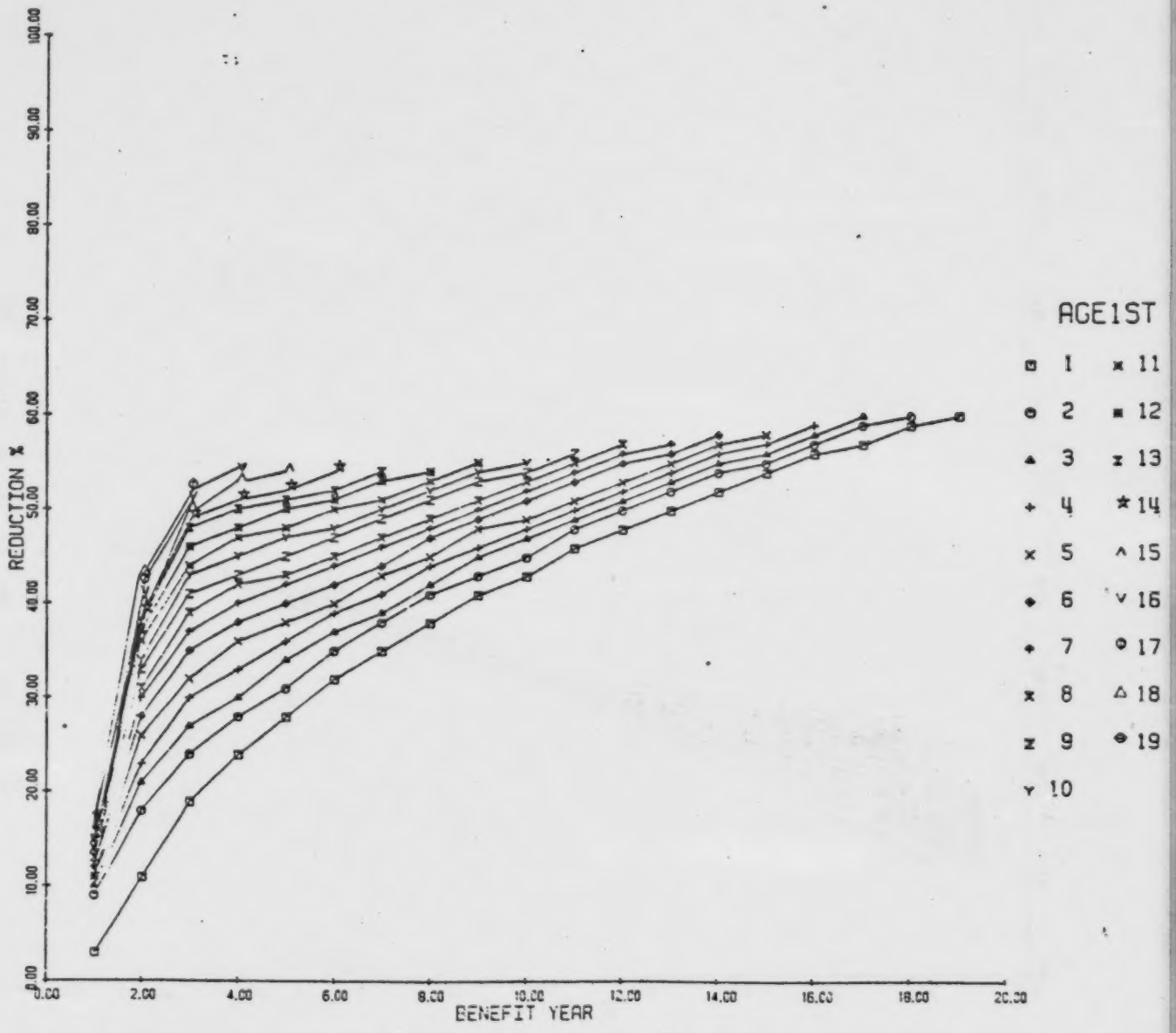


Figure 5

HC Credits for Technology II Vehicles
for a 20% Stringency I/M Program With No Mechanic Training

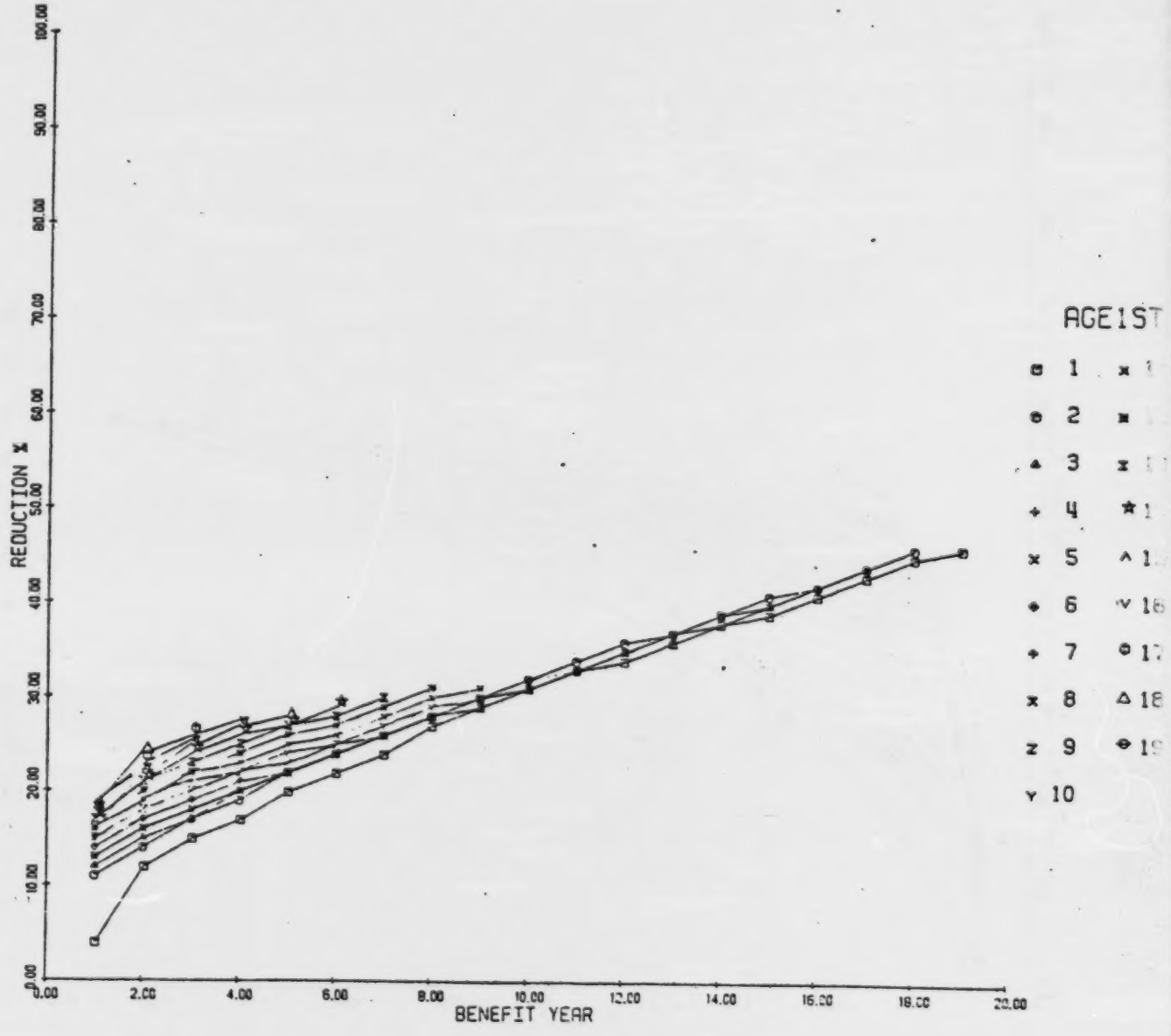


Figure 6

CO Credits for Technology II Vehicles
for a 20% Stringency I/M Program With No Mechanic Training

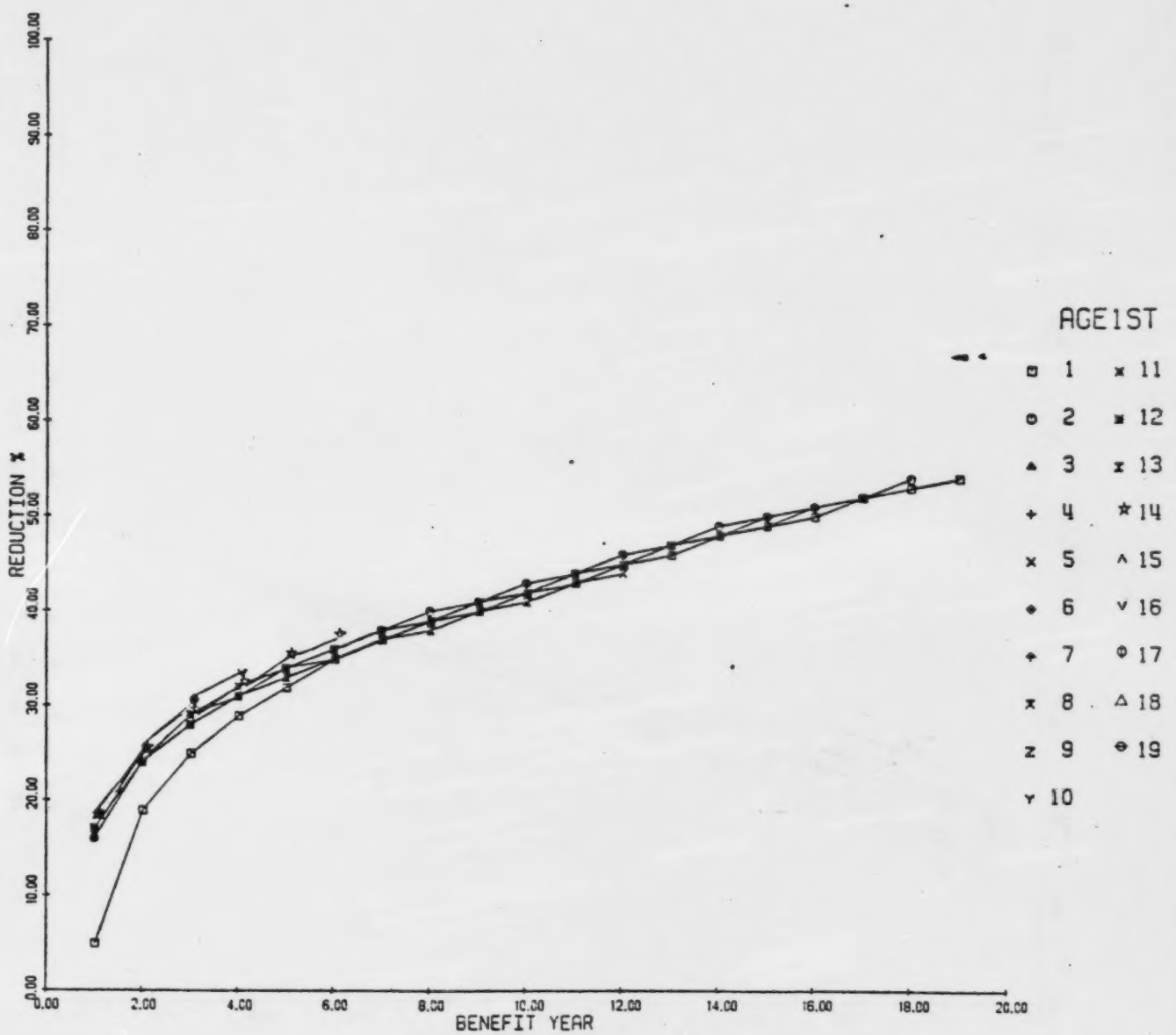


Figure 7

HC Credits for Technology II Vehicles
for a 20% Stringency I/M Program With Mechanic Training

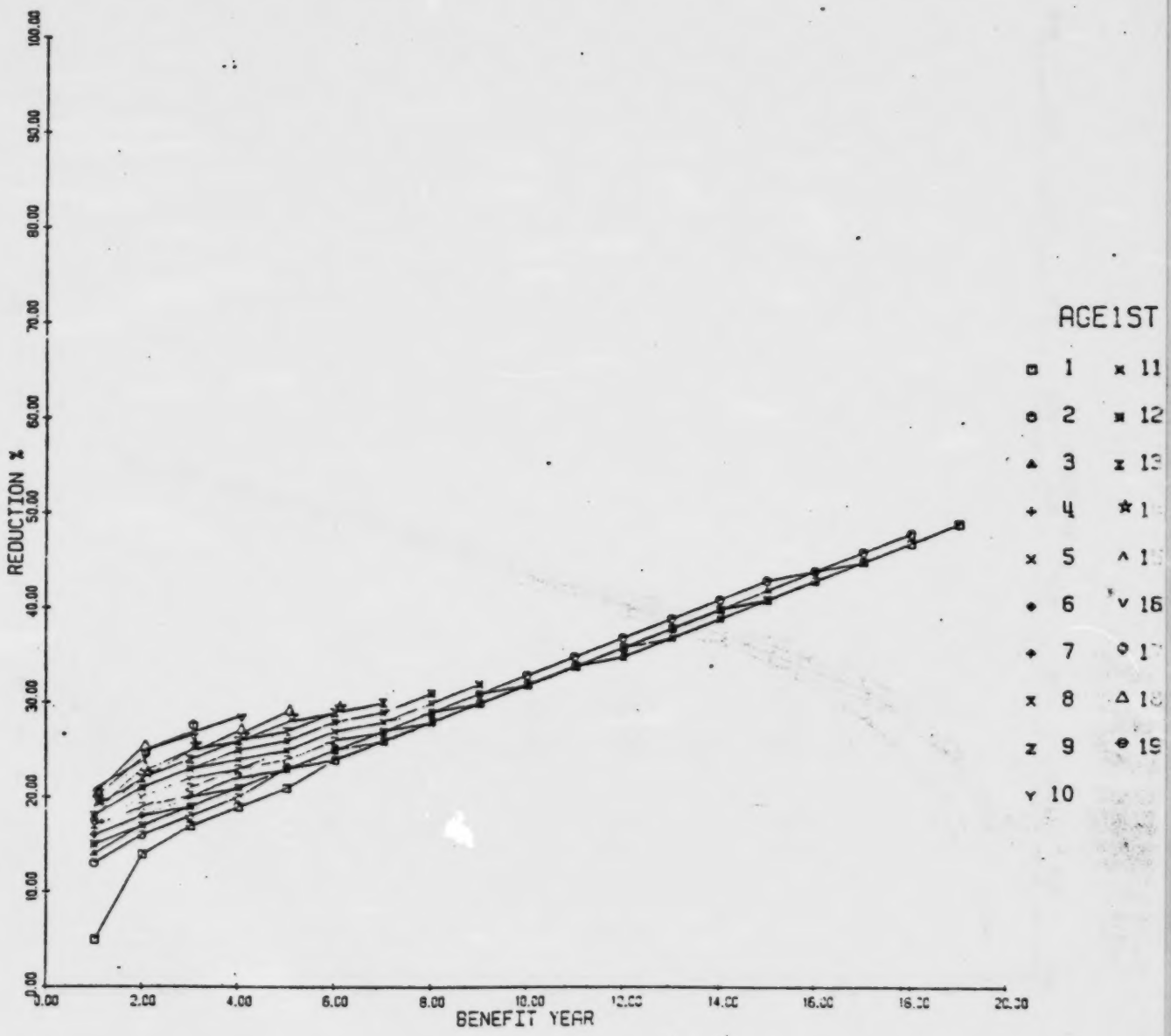


Figure 8

CO Credits for Technology II Vehicles
for a 20% Stringency I/M Program With Mechanic Training

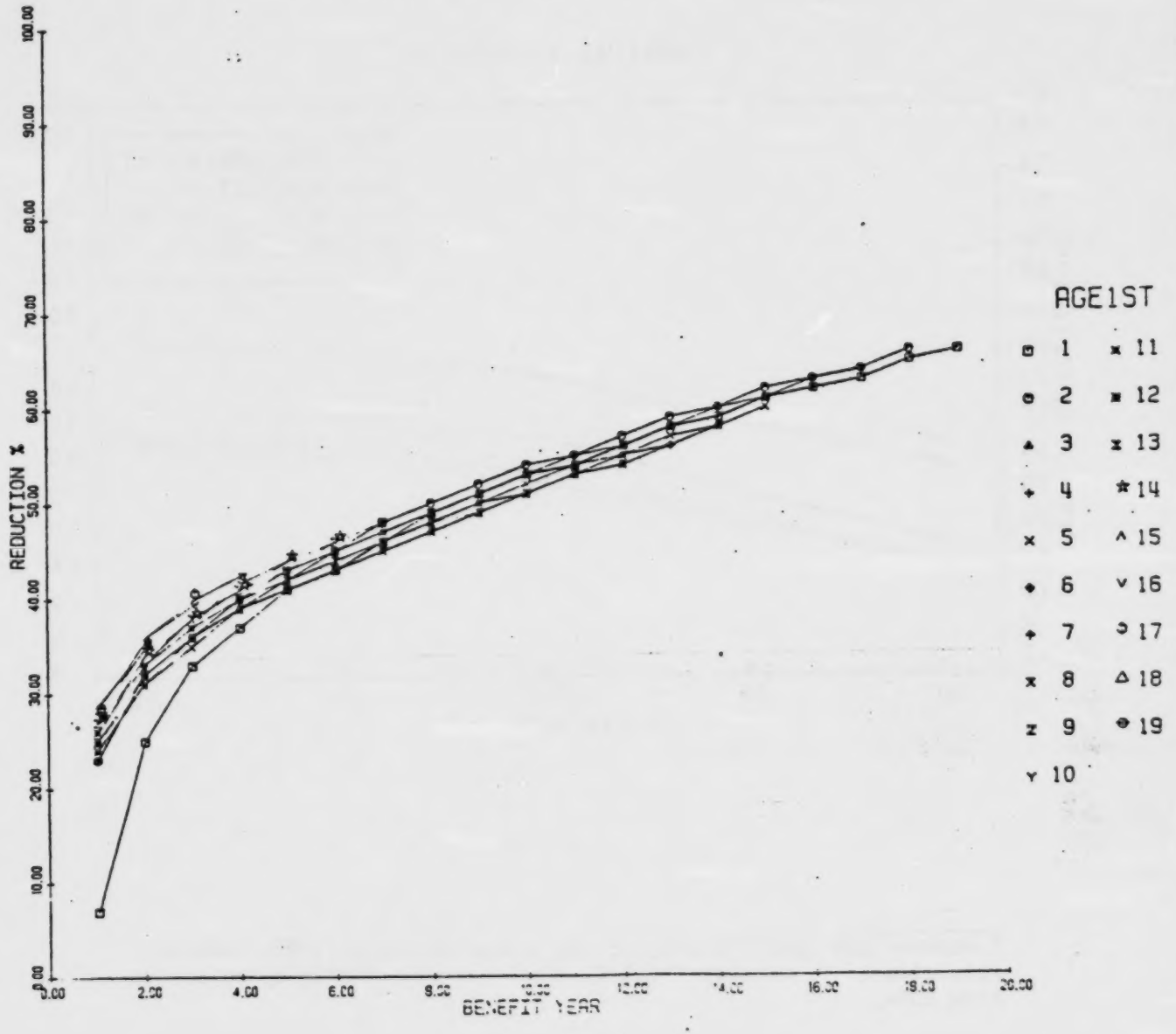
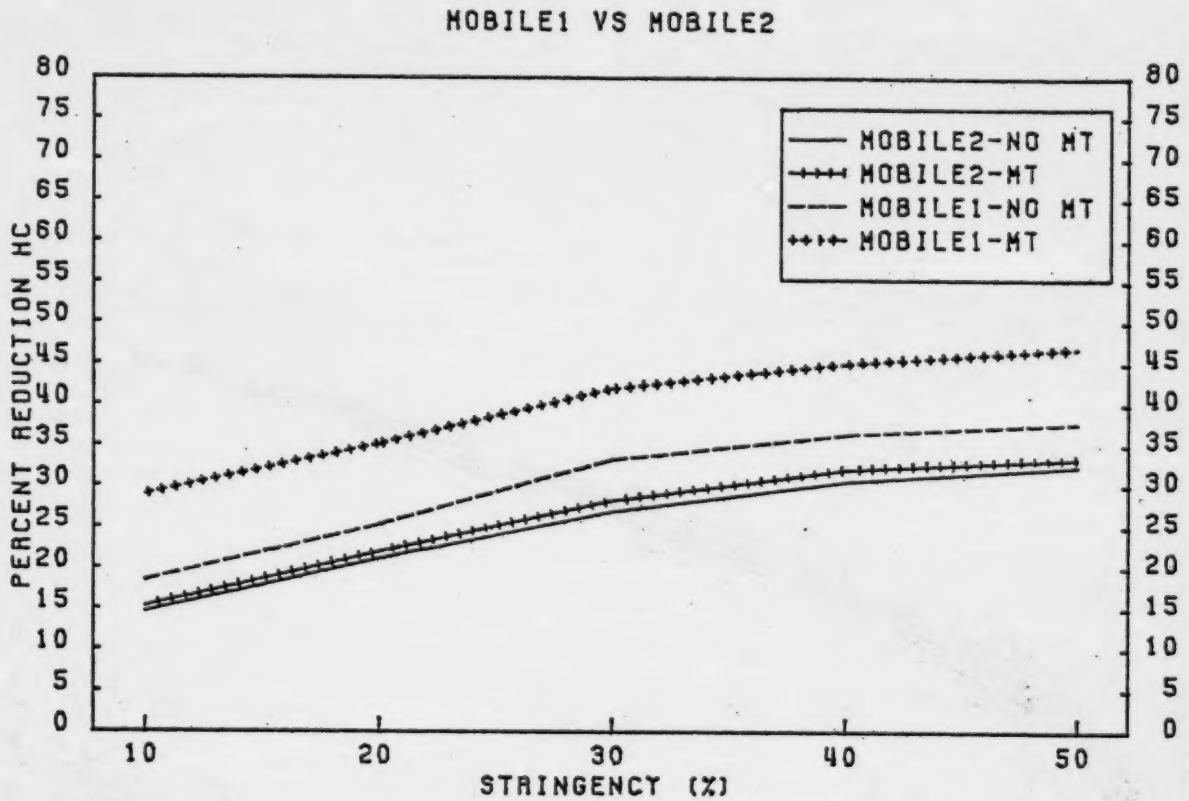


Figure 9

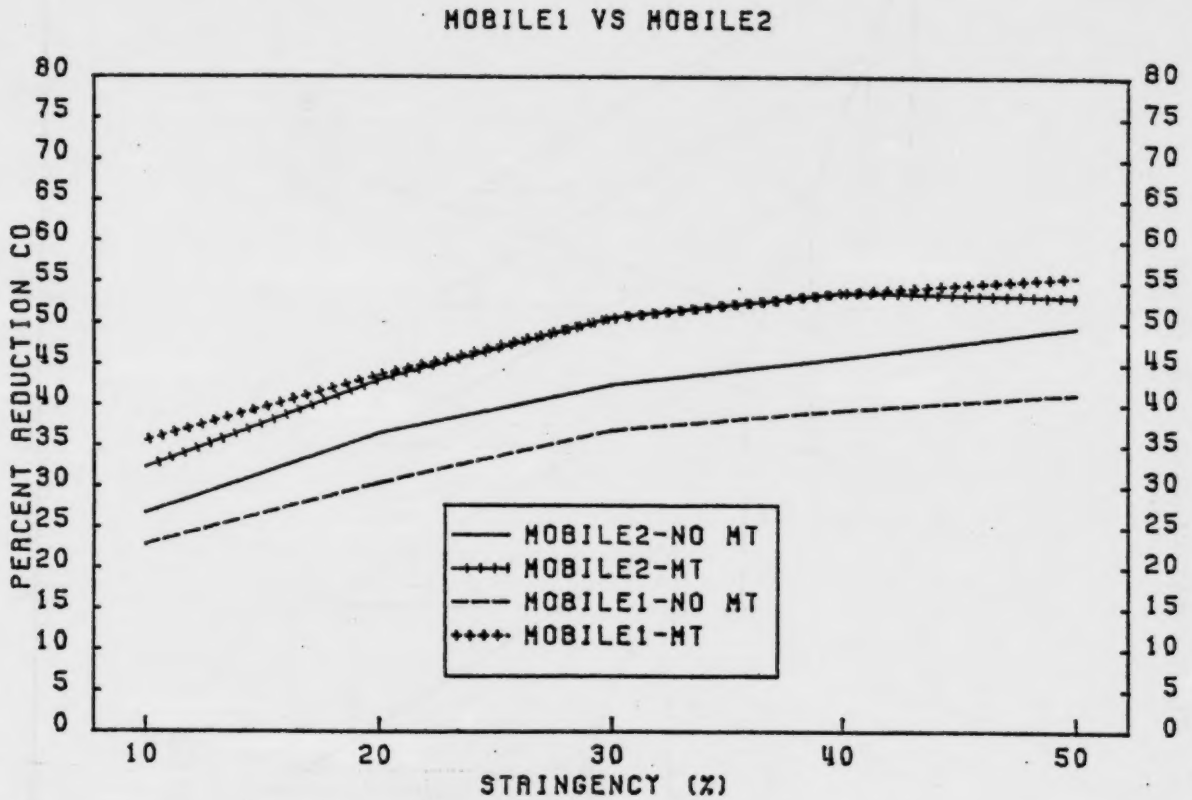
I/M Percent Reductions from January 1, 1988
HC Emission Levels Without I/M *



* Assumes LDV only I/M program beginning January 1, 1983. Percent reduction in Technology I and II total non-evaporative HC emissions from LDVs.

Figure 10

I/M Percent Reduction from Janury 1, 1988
CO Emission Levels Without I/M*



* Assumes LDV only I/M program beginning January 1, 1983. Percent reduction in Technology I and II CO emissions from LDVs.

Figure 11

Fleet Deterioration Methodology

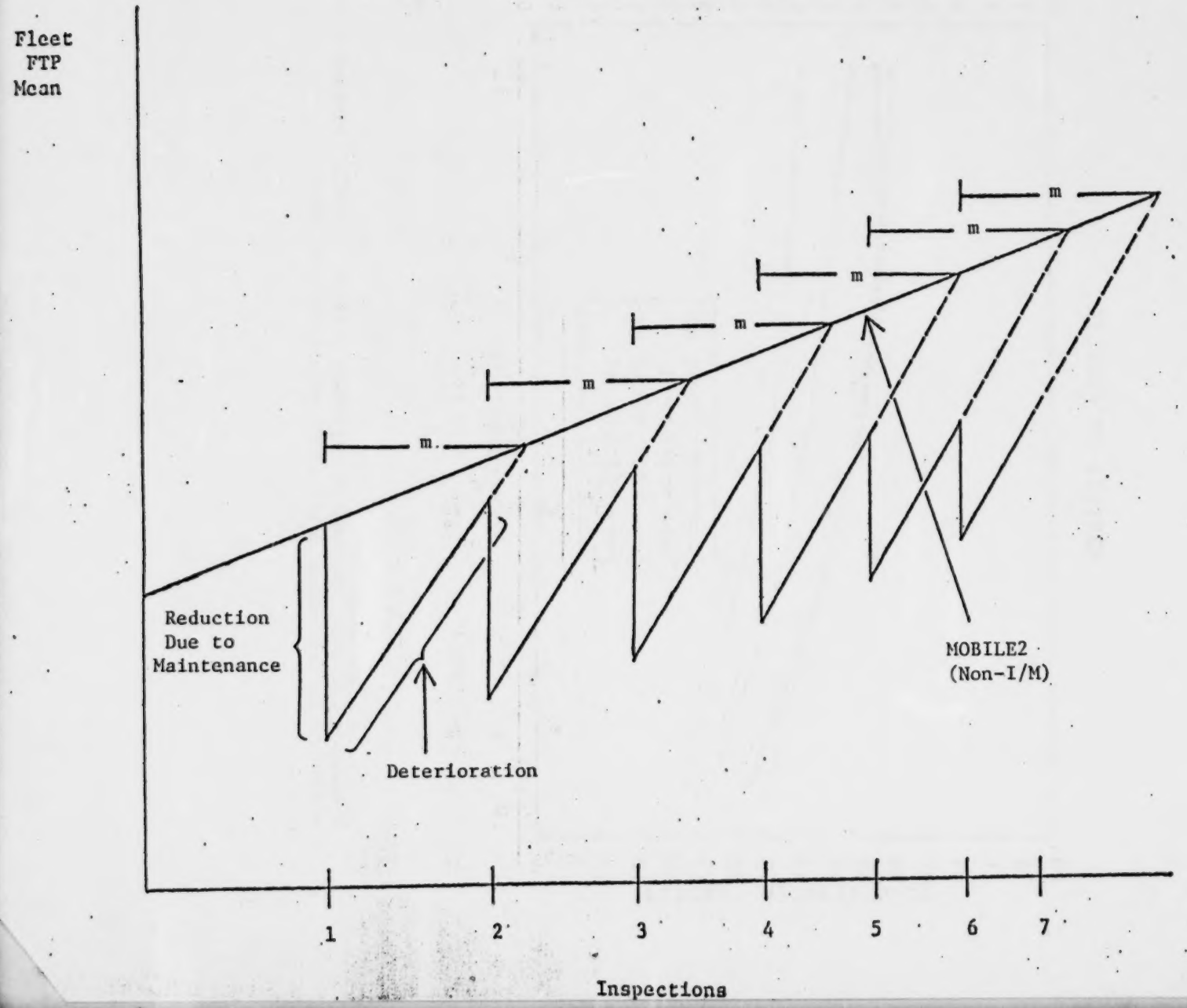


Figure 12

Emission Histories -- Age At First Inspection: 1

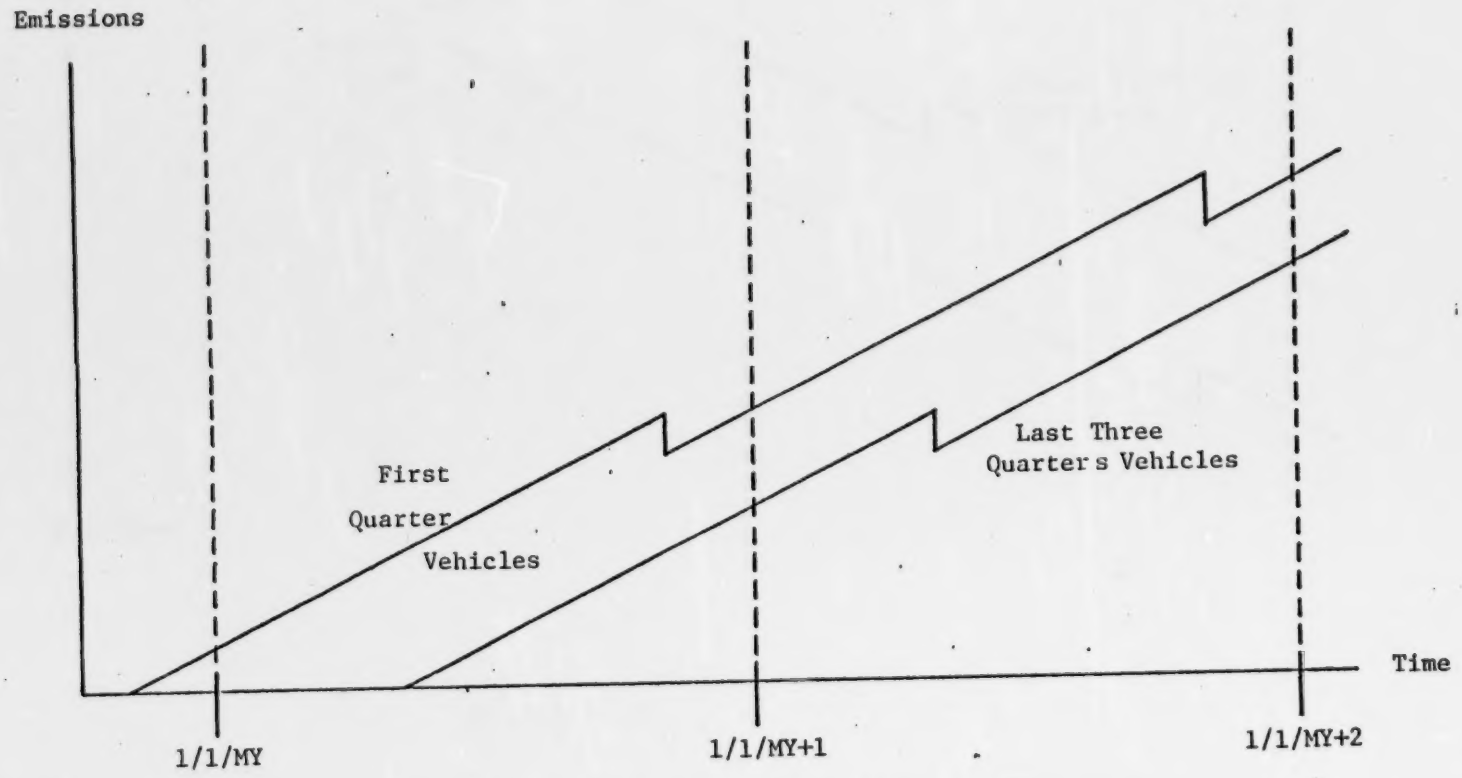
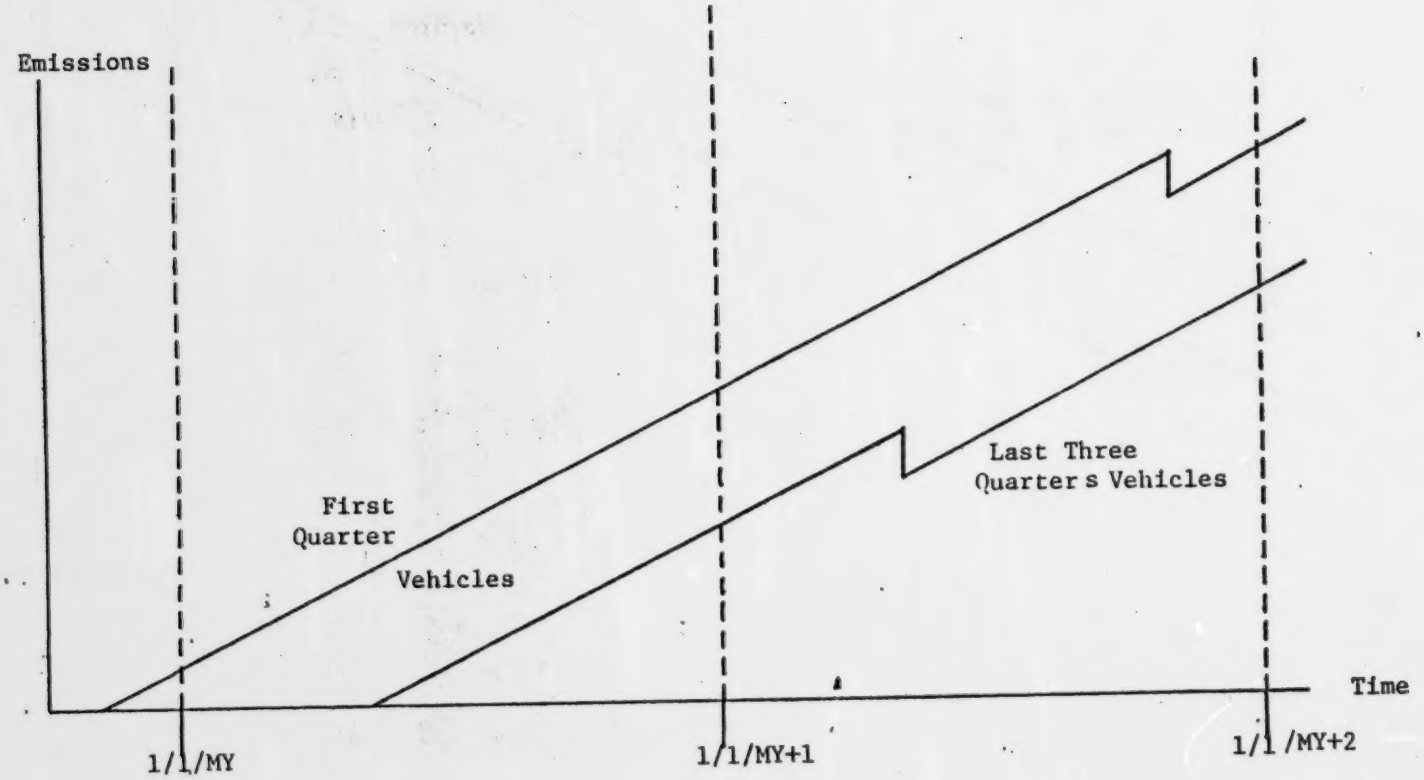


Figure 13

Emissions Histories — Age At First Inspection: 2



Appendix:

Computer Program Listing

```
C
C                  THE NEW APPENDIX N PROGRAM
C                     DESIGNED AND DEVELOPED
C            BY THE TECHNICAL AND ANALYTICAL SUPPORT GROUP
C                             I/M STAFF
C                         2565 PLYMOUTH ROAD
C                        ANN ARBOR, MICHIGAN
C
      INTEGER FIRST,AGE,ITECH,ISTRIN,MT
C
C     TO CREATE A COMPLETE MATRIX OF PERCENT EMISSION REDUCTIONS
C     RESULTING FROM AN I/M PROGRAM, THE I/M PORTION OF THE
C     VEHICLES' LIFE IS RUN ONCE FOR EACH SETUP OF THE I/M PROGRAM.
C     2 TECHNOLOGIES (ITECH)
C     5 STRINGENCY CUTPOINTS (ISTRIN)
C     0% AND 100% MECHANICS TRAINING (MT)
C     19 VEHICLE AGES OF FIRST I/M INSPECTION (FIRST)
C
      DO 30 ITECH=1,2
C
        DO 30 ISTRIN=1,5
C
          DO 30 MT=1,2
C
            DO 30 FIRST=1,19
C
C           STEP 1
C             READ IN AND INITIALIZE VARIABLES
C
              CALL INIT(FIRST,MT,ISTRIN,ITECH)
C
C           STEP 2
C             GO THROUGH THE I/M PORTION OF THE VEHICLES' LIFE
C
              DO 20 AGE=FIRST,19
                CALL SETUP(FIRST,AGE)
                CALL INSPCT(AGE)
                CALL MNTNCE(AGE)
                CALL DTRATN(AGE)
   20         CONTINUE
C
C           STEP 3
C             NOW THAT WE HAVE THE FLEET AVERAGE EMISSIONS FOR EVERY
C            YEAR, CALCULATE THE AVERAGE EMISSIONS AND PERCENT
C             REDUCTIONS ON JANUARY 1.
C
              CALL GETPR
C           STEP 4
C             STORE THE JANUARY 1 REDUCTIONS IN THE MATRIX
C             FOR INTERFACE WITH MOBILE2
```

```
C
              CALL MATRIX(MT,ISTRIN,ITECH)
C
 30   CONTINUE
      END
```

```
      SUBROUTINE INIT(FIRST,MT,ISTRIN,ITECH)
C
C     THE 'SAMPLE' COMMON BLOCK CONTAINS ALL THE INITIAL VEHICLE DATA
C     THE MAXIMUM NUMBER OF CARS IS 2678
C
C     VARIABLE            DESCRIPTION
C     ODOM(I)             THE ODOM READING FOR THE ITH CAR
C                         ALL ODOMETER READINGS ARE IN 10K MILES
C     FTP1ST(I,P)            FTP LEVEL FOR THE ITH CAR, PTH POLLUTANT
C     IDLE1ST(I,P)           IDLE LEVEL FOR THE ITH CAR, PTH POLLUTANT
C     CID(I)              CID FOR THE ITH CAR
C     PY(I)               PROGRAM YEAR
C     MY(I)               MODEL YEAR
      COMMON/SAMPLE/ODOM,FTP1ST,IDL1ST,CID,PY,MY
      INTEGER*4 CID(2678),PY(2678),MY(2678)
      REAL IDL1ST(2678,2),FTP1ST(2678,2),ODOM(2678)
C
C     THE 'CARS' COMMON BLOCK CONTAINS ALL THE ADJUSTED VEHICLE DATA
C     THE MAXIMUM NUMBER OF CARS IS 2678
C
C     VARIABLE            DESCRIPTION
C     NCARS               NUMBER OF CARS IN THIS SAMPLE
C                         MUST LESS THAN OR EQUAL TO 2678
C     ADJMIL(I)           THE ADJUSTED ODOM READING FOR THE ITH CAR
C                         ALL ODOMETER READINGS ARE IN 10K MILES
C     FTP(I,P)            FTP LEVEL FOR THE ITH CAR, PTH POLLUTANT
C     IDLE(I,P)           IDLE LEVEL FOR THE ITH CAR, PTH POLLUTANT
C     IDLRAT(I,P)         IDLE RATIO OF (ACTUAL IDLE)/(PREDICTED IDLE)
C                         USING ORIGINAL MILEAGE AND FTP'S
C     AVODOM(PY,MY)       AVERAGE ODOMETER READING  MODEL AND PROGRAM YR
C                         THERE ARE A MAXIMUM OF 15 PROGRAM YEARS
C                             AND 8 MODEL YRS
C
      COMMON/CARS/NCARS,ADJMIL,FTP,IDLE,IDLRAT,AVODOM,AVFTP
      REAL*4    FTP(2678,2),IDLE(2678,2),ADJMIL(2678),
     +AVODOM(15,8),IDLRAT(2678,2),AVFTP(15,8,2)
      INTEGER NCARS
C
C     THE 'BKGRND' COMMON BLOCK CONTAINS BACKGROUND INFORMATION
C     NEEDED TO DEFINE THE I/M PROGRAM
C
C     VARIABLE          DESCRIPTION
C     TECH              TECHNOLOGY NUMBER
C     AGE1ST            AGE OF VEHICLES AT FIRST INSPECTION
C     MTP(BY)           MECHANIC TRAINING PERCENT AT BENEFIT YEAR 'BY'
C     CUTPTS(BY,P)      IDLE CUTPOINTS AT BENEFIT YEAR 'BY'
C                       FOR POLLUTANT 'P'
C     ESTSF             ESTIMATED STRINGENCY FACTOR
C     TABLES            LOGICAL VARIABLE TO SUPRESS OUTPUT OF TABLES
C
      COMMON/BKGRND/TECH,AGE1ST,MTP,CUTPTS,ESTSF,TABLES
      INTEGER*4 TECH,AGE1ST,ESTSF
      REAL*4    CUTPTS(2,2,19,5),MTP(20)
      LOGICAL TABLES
```

```
C
C     THE 'MOB' COMMON BLOCK CONTAINS THE MOBILE2 ESTIMATES
C     OF MILEAGE AND FTP EMISSION LEVELS
C     FOR EACH TECHNOLOGY BY AGE OF VEHICLE
C
C     THESE VARIBALES ARE ALL INITIALIZED IN A BLOCK DATA STATEMENT
C
C     VARIABLE                    DESCRIPTION
C     MILES(AGE)                  ESTIMATED MILEAGE AT AGE 'AGE'
C     MOBFTP(AGE,P,TECH)          ESTIMATED FTP LEVEL AT AGE 'AGE',
C                                 TECHNOLOGY 'TECH' AND POLLUTANT 'P'
C     JMILES(AGE)                 MILEAGE ON JAN 1 CY, WHERE AGE=CY-MY
C     JFTP(AGE,P,TECH)            NON I/M FLEET FTP ON JAN 1
C     INT(P,TECH)                 MOBILE2 INTERCEPTS
C     SLOPE(P,TECH)               MOBILE2 SLOPES FOR EMISSIONS
C     STND(P,TECH)                FTP STANDARDS
C
      COMMON /MOB/ MILES, MOBFTP, JMILES, JFTP, INT, SLOPE, STND
      REAL*4 MILES(20), MOBFTP(20,2,2), JMILES(20), JFTP(20,2,2),
     1       INT(2,2), SLOPE(2,2), STND(2,2)
C     'MEANS' COMMON BLOCK CONTAINS MEAN MILEAGE,FTPHC ,FTPCO
C     WE HAVE TO MAKE OUR SAMPLE AGREE WITH THESE MEANS
C
C     VARIABLE                DESCRIPTION
C     MODOM                   MEAN ODOMETER
C     MFTP(P)                 MEAN FTP FOR POLLUTANT 'P'
C
      COMMON/MEANS/MODOM,MFTP
      REAL*4 MODOM,MFTP(2)
C
       REAL NOODOM(15,8)
      INTEGER FIRST,P,AGE,EVAL,UNIT
C
C     STEP 1
      AGE1ST=FIRST
      IF (.NOT.((ISTRIN.EQ.1)
     &    .AND.(MT.EQ.1).AND.(AGE1ST.EQ.1))) GO TO 20
C
C     READ IN THE INITIAL SAMPLE OF VEHICLES
C     THE FIRST TIME THRU
C
C
       DO  5 I=1,15
         DO  5 J=1,8
           AVODOM(I,J)=0
           NOODOM(I,J)=0
           DO  5 P=1,2
             AVFTP(I,J,P) = 0.0
 5      CONTINUE
C
C
       READ(6,7) NCARS,TABLES
    7  FORMAT(I4,L4)
```

```
C
      UNIT=7
      IF(ITECH .EQ. 2) UNIT=8
C
       DO 16 I=1,NCARS
         READ(UNIT,10) ODOM(I),FTP1ST(I,1),FTP1ST(I,2),
     &                       IDL1ST(I,1),IDL1ST(I,2),
     &                CID(I),PY(I),MY(I)
C
 10      FORMAT(F8.5,F5.2,F6.2,F5.0,F5.2,I3,1X,I1,1X,I1)
C
 14      AVODOM(PY(I),MY(I))=AVODOM(PY(I),MY(I))+ODOM(I)
         NOODOM(PY(I),MY(I))=NOODOM(PY(I),MY(I))+1
         DO 16 P=1,2
           AVFTP(PY(I),MY(I),P) = FTP1ST(I,P) + AVFTP(PY(I), MY(I), P)
16     CONTINUE
C
C
C
C
       DO 18 I=1,15
         DO 18 J=1,8
           IF (NOODOM(I,J).EQ.0) GO TO 18
           AVODOM(I,J)=AVODOM(I,J)/NOODOM(I,J)
           DO 18 P=1,2
            AVFTP(I,J,P)=AVFTP(I,J,P)/NOODOM(I,J)
   18 CONTINUE
C
C      STEP 2
C      DEFINE THE BACKGROUND INFORMATION FOR THIS I/M PROGRAM
C
   20 CONTINUE
      DO 21 P=1,2
      DO 21 I=1,NCARS
      IDLE(I,P) = IDL1ST(I,P)
      FTP(I,P) = FTP1ST(I,P)
21    CONTINUE
      TECH = ITECH
      ESTSF = ISTRIN * 10
      DO 25 I=1,20
      MTP(I) = MT - 1.
25    CONTINUE
 30   MODOM=MILES(AGE1ST)
      DO 35 P=1,2
 35      MFTP(P)=MOBFTP(AGE1ST,P,TECH)
C
C      STEP 4
C
C      SET UP THE NON I/M PORTION OF THE VEHICLES' LIFE
C      AND WRITE OUT ALL THE NON I/M EMISSION VALUES
       IF(.NOT.TABLES) GO TO 99
       WRITE(1,100)TECH,ESTSF
       WRITE(2,200)TECH,ESTSF
       WRITE(3,300)TECH,ESTSF
```

```
C     IF(AGE1ST.EQ.1) GO TO 41
C     LAST=AGE1ST-1
C     DO 40 AGE=1,LAST
C       WRITE(1,101)AGE,MILES(AGE),(MOBFTP(AGE,P,TECH),P=1,2)
C       WRITE(2,201)AGE
C     EVAL=AGE-1
C       WRITE(3,301)EVAL,JMILES(AGE),(JFTP(AGE,P,TECH),P=1,2)
C  40 CONTINUE
C  41 AGE=AGE1ST
C     EVAL=AGE-1
C       WRITE(3,301)EVAL,JMILES(AGE),(JFTP(AGE,P,TECH),P=1,2)
C
 100  FORMAT('-',T55,'I/M SIMULATION PROGRAM',T118,'TECHNOLOGY',I3/
     &T61,'TABLE 1',T100,'ESTIMATED',I3,'% STRINGENCY FACTOR'/,' ',
     &T51,'FTP AVERAGES AT EACH INSPECTION'/,'0',
     &T40,'I/M FLEET',T64,'PASSED CARS',T89,'FAILED CARS',/
     &T1,'+',T28,34('_'),T64,11('_'),T78,34('_')/
     &T53,'REDUCTION',T103,'REDUCTION    %',T125,'IDLE'/
     &T17,'NON I/M',T30,'BEFORE',T44,'AFTER',T54,'DUE TO',
     &T80,'BEFORE',T94,'AFTER',T104,'DUE TO',
     &T114,'MECH',T122,'CUTPOINTS'/
     &T3,'AGE  MILES',T18,'FLEET',T30,'MNTNCE',T43,'MNTNCE',
     &T54,'MNTNCE',T80,'MNTNCE',T93,'MNTNCE',
     &T104,'MNTNCE  TRAINING'/
     &T1,'(YRS) (10K)',T15,'HC    CO     HC    CO     HC    CO',
     &4X,'HC  CO      HC    CO     HC    CO     HC    CO',
     &4X,'HC  CO',T123,'HC   CO')
C
C101  FORMAT(I4,F7.1,2(3(F7.2,F6.1),I5,I4,2X),F6.2,F8.0,F5.1)
C
C
 200  FORMAT('-',T55,'I/M SIMULATION PROGRAM',T118,'TECHNOLOGY',I2,/
     &T61,'TABLE2',T99,'ESTIMATED',I3,'% STRINGENCY FACTOR',/
     &T1,' ',T54,'FAILURE AND ERROR RATES'/
     &T1,'0',T55,'ERRORS OF',T77,'ERRORS OF',T97,'%',T108,'IDLE',/
     &T22,'AGE',T32,'FAILURE RATE',T56,'OMISSION',T77,'COMMISSION',
     &T95,'MECH',T104,'CUTPOINTS'/
     &T1,'+',T32,12('_'),T54,12('_'),T76,12('_'),/
     &T21,'(YRS)',T27,3('     HC   CO BOTH     '),
     &T93,'TRAINING',T106,'HC   CO'//)
C
C201  FORMAT(T21,I3,3X,3(F7.2,F5.2,F5.2,5X),F5.2,F10.0,F5.1)
C
C
 300  FORMAT('-',T55,'I/M SIMULATION PROGRAM',T118,'TECHNOLOGY',I3/
     &T61,'TABLE 3',T100,'ESTIMATED',I3,'% STRINGENCY FACTOR'/,' ',
     &T49,'EMISSION INVENTORIES ON JANUARY 1'/
     &T49,'FOR I/M PROGRAM STARTING JANUARY 1'/,'0',
     &T47,'NO  I/M',T69,'I/M',T84,'PERCENT',T103,'%'/
     &T25,'AGE',T34,'MILES',T83,'REDUCTION',T101,'MECH'/
     &T24,'(YRS)',T33,'(10K)',T46,'HC',T53,'CO',T66,'HC',
     &T73,'CO',T83,'HC',T90,'CO',T100,'TRAINING'/,'+',T24,5('_'),
     &T33,5('_'),T45,4('_'),T52,4('_'),T65,4('_'),T72,4('_'),
     &T83,2('_'),T90,2('_'),T100,8('_'))
```

```
C
C 301  FORMAT(T26,I2,T33,F5.1,T44,F5.2,T51,F5.1,T64,F5.2,
C     &  T71,F5.1,T81,F4.2,T88,F4.2,T103,F3.2)
C
C
 400  FORMAT('1',T55,'I/M SIMULATION PROGRAM',T118,'TECHNOLOGY',I3/
     &T61,'TABLE 4',T100,'ESTIMATED',I3,'% STRINGENCY FACTOR'/,'0',
     &T51,'EMISSION INVENTORIES ON JULY 1'/
     &T51,'FOR I/M PROGRAM STARTING JULY 1'/,'-',
     &T47,'NO  I/M',T69,'I/M',T84,'PERCENT',T103,'%'/
     &T25,'AGE',T34,'MILES',T83,'REDUCTION',T101,'MECH'/
     &T24,'(YRS)',T33,'(10K)',T46,'HC',T53,'CO',T66,'HC',
     &T73,'CO',T83,'HC',T90,'CO',T100,'TRAINING'/,'+',T24,5('_'),
     &T33,5('_'),T45,4('_'),T52,4('_'),T65,4('_'),T72,4('_'),
     &T83,2('_'),T90,2('_'),T100,8('_'))
C
 99    RETURN
C
       END
```

```
      SUBROUTINE SETUP(FIRST,AGE)
C
C
C     THE 'BKGRND' COMMON BLOCK CONTAINS BACKGROUND INFORMATION
C     NEEDED TO DEFINE THE I/M PROGRAM
C
C     VARIABLE          DESCRIPTION
C     TECH              TECHNOLOGY NUMBER
C     AGE1ST            AGE OF VEHICLES AT FIRST INSPECTION
C     MTP(BY)           MECHANIC TRAINING PERCENT AT BENEFIT YEAR 'BY'
C     CUTPTS(BY,P)      IDLE CUTPOINTS AT BENEFIT YEAR 'BY'
C                       FOR POLLUTANT 'P'
C     ESTSF             ESTIMATED STRINGENCY FACTOR
C     TABLES            LOGICAL VARIABLE TO SUPRESS OUTPUT OF TABLES
C
      COMMON/BKGRND/TECH,AGE1ST,MTP,CUTPTS,ESTSF,TABLES
      INTEGER*4 TECH,AGE1ST,ESTSF
      REAL*4    CUTPTS(2,2,19,5),MTP(20)
      LOGICAL TABLES
C
C     THE 'CARS' COMMON BLOCK CONTAINS ALL THE ADJUSTED VEHICLE DATA
C     THE MAXIMUM NUMBER OF CARS IS 2678
C
C     VARIABLE            DESCRIPTION
C     NCARS               NUMBER OF CARS IN THIS SAMPLE
C                         MUST LESS THAN OR EQUAL TO 2678
C     ADJMIL(I)           THE ADJUSTED ODOM READING FOR THE ITH CAR
C                         ALL ODOMETER READINGS ARE IN 10K MILES
C     FTP(I,P)            FTP LEVEL FOR THE ITH CAR, PTH POLLUTANT
C     IDLE(I,P)           IDLE LEVEL FOR THE ITH CAR, PTH POLLUTANT
C     IDLRAT(I,P)         IDLE RATIO OF (ACTUAL IDLE)/(PREDICTED IDLE)
C                         USING ORIGINAL MILEAGE AND FTP'S
C     AVODOM(PY,MY)       AVERAGE ODOMETER READING  MODEL AND PROGRAM YR
C                         THERE ARE A MAXIMUM OF 15 PROGRAM YEARS
C                             AND 8 MODEL YRS
C
      COMMON/CARS/NCARS,ADJMIL,FTP,IDLE,IDLRAT,AVODOM,AVFTP
      REAL*4    FTP(2678,2),IDLE(2678,2),ADJMIL(2678),
     +AVODOM(15,8),IDLRAT(2678,2),AVFTP(15,8,2)
      INTEGER NCARS
C     'MEANS' COMMON BLOCK CONTAINS MEAN MILEAGE,FTPHC ,FTPCO
C     WE HAVE TO MAKE OUR SAMPLE AGREE WITH THESE MEANS
C
C     VARIABLE            DESCRIPTION
C     MODOM               MEAN ODOMETER
C     MFTP(P)             MEAN FTP FOR POLLUTANT 'P'
C
      COMMON/MEANS/MODOM,MFTP
      REAL*4 MODOM,MFTP(2)
C
C     THE 'SAMPLE' COMMON BLOCK CONTAINS ALL THE INITIAL VEHICLE DATA
C     THE MAXIMUM NUMBER OF CARS IS 2678
```

```
C
C     VARIABLE              DESCRIPTION
C     ODOM(I)               THE ODOM READING FOR THE ITH CAR
C                           ALL ODOMETER READINGS ARE IN 10K MILES
C     FTP1ST(I,P)              FTP LEVEL FOR THE ITH CAR, PTH POLLUTANT
C     IDLE1ST(I,P)             IDLE LEVEL FOR THE ITH CAR, PTH POLLUTANT
C     CID(I)                CID FOR THE ITH CAR
C     PY(I)                 PROGRAM YEAR
C     MY(I)                 MODEL YEAR
      COMMON/SAMPLE/ODOM,FTP1ST,IDL1ST,CID,PY,MY
      INTEGER*4 CID(2678),PY(2678),MY(2678)
      REAL IDL1ST(2678,2),FTP1ST(2678,2),ODOM(2678)
C
C
C
C
C
C
      INTEGER P,FIRST,AGE,T
      REAL LEVEL
      REAL SMALL(2),RATIO(3),BETA(5,2,2,2)
C     BETA(1-5,HC/CO,INITIAL/AFTER MAINTENANCE,TECH)
      DATA SMALL/1.0,.01/
C
      DATA BETA/140.36, 6.17, 76.32, -1.18, -.30,
     &          2.3972, .0120, .0532, .0472, -.0055,
     &          -131.35, 24.94, 28.08, 11.20, -1.00,
     &          .6558, -.0206, .0382, .0642, -.0051,
     &           11.12,-1.65,102.23,-.32,.03,
     &          .4258,-.0118,.0843,.0681,-.0017,
     &          -11.64,-2.18,59.22,1.31,.12,
     &          .4796,-.0672,.0398,.0655,-.0011/
C
C.....STEP 1
C.....DO ALL THE INITIAL PROCESSING FOR THE FIRST SETUP
C
      IF(FIRST.NE.AGE) GO TO 15
      T=1
       IF(FIRST .NE. 1) GO TO 11
      DO 10 I=1,NCARS
C
      DO 10 P=1,2
C
C     STEP 1.2
C     FIND PREDICTED IDLE BASED ON ACTUAL FTP'S AND MILEAGE
C     COMPUTE 'IDLRAT' : ACTUAL/PREDICTED
      PREDCT = AMAX1(SMALL(P), ( BETA(1,P,T,TECH) +
     &                           BETA(2,P,T,TECH)*ODOM(I) +
     &                           BETA(3,P,T,TECH)*FTP(I,1) +
     &                           BETA(4,P,T,TECH)*FTP(I,2)  +
     &                           BETA(5,P,T,TECH)*CID(I)   ))
      IDLRAT(I,P)= IDLE(I,P) / PREDCT
   10 CONTINUE
```

```
C
   11 DO 12 I=1,NCARS
C     STEP 1.1
C     ADJUST THE MILEAGES SO THAT THE FLEET AVERAGE ODOM
C     EQUALS THE TARGET MEAN 'MODOM'
      ADJMIL(I)=ODOM(I)*MODOM/AVODOM(PY(I),MY(I))
C
      DO 12 P=1,2
C     STEP 1.3
C     ADJUST FTP ACCORDING TO PY, MY STRATIFICATION
      FTP(I,P) = FTP(I,P) * MFTP(P) / AVFTP(PY(I), MY(I), P)
 12   CONTINUE
      GO TO 31
C
C
C.....STEP 2
C.....DO ALL THE PROCESSING NEEDED WHEN ITS NOT THE FIRST TIME THROUGH
 15   T=2
C     STEP 2.1
C     ADJUST THE MILEAGES SO THAT THE FLEET AVERAGE ODOM
C     EQUALS THE TARGET MEAN 'MODOM'
      RATIO(3)=MODOM/AVER(NCARS,ADJMIL)
 20   DO 25 I=1,NCARS
      ADJMIL(I)=ADJMIL(I)*RATIO(3)
 25   CONTINUE
C
C
C.....STEP 3
C.....EVERYBODY GOES THROUGH THIS PART
C     STEP 3.1
C     ADJUST THE FTP'S SO THAT THE AVERAGE FLEET FTP'S
C     EQUAL THE TARGET MEANS 'MFTP'
 31   DO 32 P=1,2
 32      RATIO(P)=MFTP(P)/AVER(NCARS,FTP(1,P))
      DO 35 I=1,NCARS
      DO 35 P=1,2
         FTP(I,P)=FTP(I,P)*RATIO(P)
C
C     STEP 3.2
C     ADUST THE IDLE LEVELS
      LEVEL = BETA(1,P,T,TECH) +
     &  BETA(2,P,T,TECH)*ADJMIL(I) +
     &  BETA(3,P,T,TECH)*FTP(I,1) +
     & BETA(4,P,T,TECH)*FTP(I,2)  +
     & BETA(5,P,T,TECH)*CID(I)
      IF(LEVEL.GT.SMALL(P)) GOTO 33
        LEVEL = SMALL(P)
 33   CONTINUE
      IDLE(I,P) = IDLRAT(I,P) * LEVEL
 35   CONTINUE
C
 99   RETURN
      END
```

```
      SUBROUTINE INSPCT(AGE)
C
C     THE 'CARS' COMMON BLOCK CONTAINS ALL THE ADJUSTED VEHICLE DATA
C     THE MAXIMUM NUMBER OF CARS IS 2678
C
C     VARIABLE            DESCRIPTION
C     NCARS               NUMBER OF CARS IN THIS SAMPLE
C                         MUST LESS THAN OR EQUAL TO 2678
C     ADJMIL(I)           THE ADJUSTED ODOM READING FOR THE ITH CAR
C                         ALL ODOMETER READINGS ARE IN 10K MILES
C     FTP(I,P)            FTP LEVEL FOR THE ITH CAR, PTH POLLUTANT
C     IDLE(I,P)           IDLE LEVEL FOR THE ITH CAR, PTH POLLUTANT
C     IDLRAT(I,P)         IDLE RATIO OF (ACTUAL IDLE)/(PREDICTED IDLE)
C                         USING ORIGINAL MILEAGE AND FTP'S
C     AVODOM(PY,MY)       AVERAGE ODOMETER READING  MODEL AND PROGRAM YR
C                         THERE ARE A MAXIMUM OF 15 PROGRAM YEARS
C                             AND 8 MODEL YRS
C
      COMMON/CARS/NCARS,ADJMIL,FTP,IDLE,IDLRAT,AVODOM,AVFTP
      REAL*4    FTP(2678,2),IDLE(2678,2),ADJMIL(2678),
     +AVODOM(15,8),IDLRAT(2678,2),AVFTP(15,8,2)
      INTEGER NCARS
C     'MEANS' COMMON BLOCK CONTAINS MEAN MILEAGE,FTPHC ,FTPCO
C     WE HAVE TO MAKE OUR SAMPLE AGREE WITH THESE MEANS
C
C     VARIABLE              DESCRIPTION
C     MODOM                 MEAN ODOMETER
C     MFTP(P)               MEAN FTP FOR POLLUTANT 'P'
C
      COMMON/MEANS/MODOM,MFTP
      REAL*4 MODOM,MFTP(2)
C
C     THE 'BKGRND' COMMON BLOCK CONTAINS BACKGROUND INFORMATION
C     NEEDED TO DEFINE THE I/M PROGRAM
C
C     VARIABLE          DESCRIPTION
C     TECH              TECHNOLOGY NUMBER
C     AGE1ST            AGE OF VEHICLES AT FIRST INSPECTION
C     MTP(BY)           MECHANIC TRAINING PERCENT AT BENEFIT YEAR 'BY'
C     CUTPTS(BY,P)      IDLE CUTPOINTS AT BENEFIT YEAR 'BY'
C                       FOR POLLUTANT 'P'
C     ESTSF             ESTIMATED STRINGENCY FACTOR
C     TABLES            LOGICAL VARIABLE TO SUPRESS OUTPUT OF TABLES
C
      COMMON/BKGRND/TECH,AGE1ST,MTP,CUTPTS,ESTSF,TABLES
      INTEGER*4 TECH,AGE1ST,ESTSF
      REAL*4    CUTPTS(2,2,19,5),MTP(20)
      LOGICAL TABLES
C
C     THE 'MOB' COMMON BLOCK CONTAINS THE MOBILE2 ESTIMATES
C     OF MILEAGE AND FTP EMISSION LEVELS
C     FOR EACH TECHNOLOGY BY AGE OF VEHICLE
```

```
C
C     THESE VARIBALES ARE ALL INITIALIZED IN A BLOCK DATA STATEMENT
C
C     VARIABLE                    DESCRIPTION
C     MILES(AGE)                  ESTIMATED MILEAGE AT AGE 'AGE'
C     MOBFTP(AGE,P,TECH)          ESTIMATED FTP LEVEL AT AGE 'AGE',
C                                 TECHNOLOGY 'TECH' AND POLLUTANT 'P'
C     JMILES(AGE)                 MILEAGE ON JAN 1 CY, WHERE AGE=CY-MY
C     JFTP(AGE,P,TECH)            NON I/M FLEET FTP ON JAN 1
C     INT(P,TECH)                 MOBILE2 INTERCEPTS
C     SLOPE(P,TECH)               MOBILE2 SLOPES FOR EMISSIONS
C     STND(P,TECH)                FTP STANDARDS
C
      COMMON /MOB/ MILES, MOBFTP, JMILES, JFTP, INT, SLOPE, STND
      REAL*4 MILES(20), MOBFTP(20,2,2), JMILES(20), JFTP(20,2,2),
     1       INT(2,2), SLOPE(2,2), STND(2,2)
C
C     'HSTRY' COMMON BLOCK CONTAINS EMISSION HISTORY THROUGHOUT PROGRAM
C
C     VARIABLE                     DESCRIPTION
C     TFB(AGE,P)                   TOTAL FLEET FTP BEFORE INSPECTION
C     TFA(AGE,P)                   TOTAL FLEET FTP AFTER INSPECTION
C     F                            F=1 PASSED THE TEST
C                                   =2 FAILED FOR HC ONLY
C                                   =3 FAILED FOR CO ONLY
C                                   =4 FAILED FOR BOTH
C     NF(F)                        NUMBER IN EACH GROUP
C     TOTFTP(P,F)                  TOTAL FTP IN EACH GROUP
C     PR(P,BY)                     PERCENT REDUCTION ON JANUARY 1ST
C     AVGMIL(F)                    AVERAGE MILEAGE FOR FAILURE GROUP
C
      COMMON/HSTRY/ TFB,TFA,NF,TOTFTP,AVGMIL,PR
      REAL*4 TFB(20,2),TFA(20,2),TOTFTP(2,4),AVGMIL(4)
      INTEGER*4 NF(4),PR(2,20)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      LOGICAL*1 PASS(2,3)
      INTEGER*2 NFAIL(3),NEO(3),NEC(3),FTEST,ITEST,TEST,HC,CO,P,FGRP
      INTEGER*4 AGE
      REAL*4 FR(3),EC(3),EO(3)
C
C     VARIABLE          DESCRIPTION
C     PASS(FTEST,HC)     TRUE IF CAR PASSES FTP HC
C     PASS(ITEST,HC)    TRUE IF CAR PASSES IDLE HC
C     PASS(FTEST,CO)     TRUE IF CAR PASSES FTP CO
C     PASS(ITEST,CO)    TRUE IF CAR PASSES IDLE CO
C     NFAIL(HC)          NUMBER OF CARS FAILING IDLE HC
C     NFAIL(CO)          NUMBER OF CARS FAILING IDLE CO
C     NFAIL(TEST)        NUMBER OF CARS FAILING IDLE TEST
C     FR(P)                    FAILURE RATE P:1 HC, 2 CO, 3 OVERALL
C     EC(P)                    ERRORS OF COMMISSION
C     EO(P)                    ERRORS OF OMISSION
```

```
C
      FTEST=1
      ITEST=2
      HC=1
      CO=2
      TEST=3
C
C     STEP 1
C     INITIALIZE
      ISTRIN=ESTSF/10
      DO 10 P=1,3
        NFAIL(P)=0
        NEC(P)=0
        NEO(P)=0
        FR(P)=0
        EC(P)=0
        EO(P)=0
 10   CONTINUE
C
        DO 11 FGRP=1,4
          NF(FGRP)=0
          AVGMIL(FGRP) = 0.0
      DO 11 P=1,2
          TOTFTP(P,FGRP)=0
 11   CONTINUE
C
C
C     STEP 2
C     FIND OUT WHO PASSED AND WHO FAILED
      DO 29 I=1,NCARS
        DO 13 J=1,2
          DO 13 K=1,3
 13         PASS(J,K) = .TRUE.
        FGRP=0
        DO 25 P=1,2
C
C     DID THEY PASS FTP FOR THIS POLLUTANT?
          IF(FTP(I,P).LT.STND(P,TECH))GO TO 22
            PASS(FTEST,P)=.FALSE.
            PASS(FTEST,TEST)=.FALSE.
C
C     DID THEY PASS IDLE FOR THIS POLLUTANT?
 22       IF(IDLE(I,P).LE.CUTPTS(P,TECH,AGE1ST,ISTRIN))GO TO 25
            FGRP=FGRP+P
            NFAIL(P)=NFAIL(P)+1
            PASS(ITEST,P)=.FALSE.
            PASS(ITEST,TEST)=.FALSE.
C
C
 25     CONTINUE
C
```

```
C     ADD FTP'S TO THE PROPER GROUP
      FGRP=FGRP+1
      AVGMIL(FGRP) = AVGMIL(FGRP) + ADJMIL(I)
      NF(FGRP)=NF(FGRP)+1
      TOTFTP(HC,FGRP)=TOTFTP(HC,FGRP)+FTP(I,HC)
      TOTFTP(CO,FGRP)=TOTFTP(CO,FGRP)+FTP(I,CO)
C
C     ANY ERRORS OF COMMISSION OR OMISSION?
        DO 27 P=1,3
          IF(PASS(ITEST,P) .AND. .NOT.PASS(FTEST,P))
     &      NEO(P)=NEO(P)+1
          IF(.NOT.PASS(ITEST,P) .AND. PASS(FTEST,P))
     &      NEC(P)=NEC(P)+1
 27     CONTINUE
C
 29   CONTINUE
C
C     STEP 3
C     FIND TOTALS AND FAILURE AND ERROR RATES
      NFAIL(TEST)=NCARS - NF(1)
C
C   Calculate average mileage in each failure group
      DO 34 FGRP=1,4
        IF (NF(FGRP) .NE. 0) AVGMIL(FGRP)=AVGMIL(FGRP) / NF(FGRP)
34    CONTINUE
      DO 39 P=1,3
        FR(P)=1.0*NFAIL(P)/NCARS
        EC(P)=1.0*NEC(P)/NCARS
        EO(P)=1.0*NEO(P)/NCARS
 39   CONTINUE
C
C     STEP 4
C     WRITE OUT THE FAILURE AND ERROR RATES
      IF (.NOT. TABLES) GOTO 99
      IMTP=MTP(AGE)*100.+.5
      WRITE(2,201)AGE,(FR(P),P=1,3),(EO(P),P=1,3),(EC(P),P=1,3),
     + IMTP ,(CUTPTS(P,TECH,AGE1ST,ISTRIN),P=1,2)
C
C
 201  FORMAT(T21,I3,4X,3(F7.2,F5.2,F5.2,5X),I5,F10.0,F5.1)
C
99    RETURN
      END
```

```
      SUBROUTINE MNTNCE(AGE)
C
C     THE 'BKGRND' COMMON BLOCK CONTAINS BACKGROUND INFORMATION
C     NEEDED TO DEFINE THE I/M PROGRAM
C
C     VARIABLE          DESCRIPTION
C     TECH              TECHNOLOGY NUMBER
C     AGE1ST            AGE OF VEHICLES AT FIRST INSPECTION
C     MTP(BY)           MECHANIC TRAINING PERCENT AT BENEFIT YEAR 'BY'
C     CUTPTS(BY,P)      IDLE CUTPOINTS AT BENEFIT YEAR 'BY'
C                       FOR POLLUTANT 'P'
C     ESTSF             ESTIMATED STRINGENCY FACTOR
C     TABLES            LOGICAL VARIABLE TO SUPRESS OUTPUT OF TABLES
C
      COMMON/BKGRND/TECH,AGE1ST,MTP,CUTPTS,ESTSF,TABLES
      INTEGER*4 TECH,AGE1ST,ESTSF
      REAL*4    CUTPTS(2,2,19,5),MTP(20)
      LOGICAL TABLES
C
C     'HSTRY' COMMON BLOCK CONTAINS EMISSION HISTORY THROUGHOUT PROGRAM
C
C     VARIABLE                  DESCRIPTION
C     TFB(AGE,P)                TOTAL FLEET FTP BEFORE INSPECTION
C     TFA(AGE,P)                TOTAL FLEET FTP AFTER INSPECTION
C     F                         F=1 PASSED THE TEST
C                                =2 FAILED FOR HC ONLY
C                                =3 FAILED FOR CO ONLY
C                                =4 FAILED FOR BOTH
C     NF(F)                     NUMBER IN EACH GROUP
C     TOTFTP(P,F)               TOTAL FTP IN EACH GROUP
C     PR(P,BY)                  PERCENT REDUCTION ON JANUARY 1ST
C     AVGMIL(F)                 AVERAGE MILEAGE FOR FAILURE GROUP
C
      COMMON/HSTRY/ TFB,TFA,NF,TOTFTP,AVGMIL,PR
      REAL*4 TFB(20,2),TFA(20,2),TOTFTP(2,4),AVGMIL(4)
      INTEGER*4 NF(4),PR(2,20)
C
C     THE 'MOB' COMMON BLOCK CONTAINS THE MOBILE2 ESTIMATES
C     OF MILEAGE AND FTP EMISSION LEVELS
C     FOR EACH TECHNOLOGY BY AGE OF VEHICLE
C
C     THESE VARIBALES ARE ALL INITIALIZED IN A BLOCK DATA STATEMENT
C
C     VARIABLE                  DESCRIPTION
C     MILES(AGE)                ESTIMATED MILEAGE AT AGE 'AGE'
C     MOBFTP(AGE,P,TECH)        ESTIMATED FTP LEVEL AT AGE 'AGE',
C                               TECHNOLOGY 'TECH' AND POLLUTANT 'P'
C     JMILES(AGE)               MILEAGE ON JAN 1 CY, WHERE AGE=CY-MY
C     JFTP(AGE,P,TECH)          NON I/M FLEET FTP ON JAN 1
C     INT(P,TECH)               MOBILE2 INTERCEPTS
C     SLOPE(P,TECH)             MOBILE2 SLOPES FOR EMISSIONS
C     STND(P,TECH)              FTP STANDARDS
```

```
C
      COMMON /MOB/ MILES, MOBFTP, JMILES, JFTP, INT, SLOPE, STND
      REAL*4 MILES(20), MOBFTP(20,2,2), JMILES(20), JFTP(20,2,2),
     1       INT(2,2), SLOPE(2,2), STND(2,2)
C
C     This subroutine performs maintenance on failed cars.
C     The after maintenance mean ftp emissions for pollutant p (p=1,hc; p=2,co)
C     and failure group (hcpass?, copass?) is given for each technology
C     by
C        ftp(hcpass,copass,p) = d(hcpass,copass,p,0) + d(hcpass,copass,p,1)*
mean mileage(hcpass,copass)
C       + d(hcpass,copsas,p,4)* idlehc cutpoints + d(hcpass, copass, p, 5) *
idleco cutpoints
C
C     Variables are used as follows:
C     amftp(hcpass, copass, technology, with without mechanic training)
C       is the After Maintenance FTP
C
C
      INTEGER*2 P,FGRP
      INTEGER*4 TFPR(2),FFPR(2),AGE
      REAL*4 PF(2),FFB(2),FFA(2)
C     VARIABLE                    DESCRIPTION
C
C     TFPR(P)                     TOTAL FLEET % REDUCTION IN FTP
C                                 DUE TO MAINTENANCE
C     PF(P)                       PASSED FLEET EMISSION
C     FFB(P)                      FAILED FLEET FTP BEFORE MNTNCE
C     FFA(P)                      FAILED FLEET FTP AFTER MNTNCE
C     FFPR(P)                     FAILED FLEET % REDUCTION IN FTP
C                                 DUE TO MAINTENANCE
C
C     THIS ROUTINE MUST SIMULATE MAINTENANCE
C     THE 'FFA'(FAILED FLEET AFTER MAINTENANCE) VARIABLE AND
C     'TFA'(TOTAL  FLEET AFTER MAINTENANCE) MUST BE COMPUTED
C
C
C     STEP 1
C
C     GRP(FGRP)       where GRP =
C                     1 if pass idle hc and co
C                     2  if fail idle hc
C                     3 if fail idle co
C                     4 if fail both idle hc and co
C     D(hcpass?, copass?, pollutant, tech) and
C          are parameters determined from statistical analysis
C     DPRIME(hcpass?, copass?, pollutant, tech)
C          are parameters determined for calculating  after
C          maintenance values for cars with mechanic training
C     AMFTP(hcpass?, copass?, p, with/without mechanic training
C          is the after maintenance FTP level.
```

```
C
      INTEGER GRP(2,2)/1, 2, 3, 4/
      REAL AMFTP(2, 2, 2, 2),IREG(2)
      REAL A(2,3,2)/ 59.396 , -.6596 , 8.2111 , .0615 , 12.106 , .4658 ,
     *               27.814 , -.2716 , 4.6612 , 0.0   , 18.517 , .3905 /
      REAL C(2,2,2,2,4)/
     *0.0, 2.8093 , 2.4490 , 1.0398 ,0.0, 41.933 , 23.007 , 43.096 ,
     *0.0, 1.0906 , .80638 , 1.0855 ,0.0, 16.275 , 14.391 , 16.379 ,
     *0.0, 0.0    ,-.20922 , .21054 ,0.0,  0.0   , 1.3794 ,  0.0   ,
     *0.0, 0.0    , .21934 , .14956 ,0.0,  0.0   , 1.3610 , 1.7465 ,
     *0.0, 0.0    ,.012067 ,.004185 ,0.0,  0.0   , 0.0    , 0.0    ,
     *0.0, .00464 , 0.0    ,.0014085,0.0, 0.0    , 0.0    , 0.0    ,
     *0.0, 0.0    , 0.0    , 0.0    ,0.0, 0.0    , 6.6541 , 0.0    ,
     *0.0, 0.0    , 0.0    , 0.0    ,0.0, 28.224 ,-.021437, 9.6023 /
      REAL DPRIME(2,2,2,2)/
     *0.0, 3.7504 , 3.7504 , 3.7504 ,0.0, 37.49   , 37.49   , 37.49   ,
     *0.0, 1.4671 , .32275 , 1.2418 ,0.0, 11.358  ,  5.1816 , 17.687  /
      REAL D(2,2,2,2)/
     *0.0, -.0624, -.0624 ,-.0624 ,0.0,.33, .33    , .33    ,
     *0.0, .0243 , .20266 , .16849,0.0,0.0, 1.2501 , 1.7631 /
      REAL K(2,2,2,2)/
     *0.0, .96569 , 1.0647 , 1.1575 ,0.0, .65245 , .99755 , 1.0489 ,
     *0.0, 1.1237 , .92395 , 1.0792 ,0.0, 1.0771 , .91849 , 1.0095 /
      INTEGER BY,HCPASS,COPASS,WITH/1/,WTHOUT/2/
C
      IF(AGE .GT. AGE1ST) GO TO 2
      DO 1 P=1,2
    1 TFB(AGE,P)=MOBFTP(AGE,P,TECH)
    2 CONTINUE
      ISTRIN=ESTSF/10
      BY = AGE - AGE1ST + 1
      NUMFLD = NF(2) + NF(3) + NF(4)
C
      DO 5 P=1,2
        PF(P) = 0
        FFB(P) = 0
        IF (NF(1) .NE. 0) PF(P) = TOTFTP(P,1) / NF(1)
        IF(NUMFLD .NE. 0) FFB(P) =
     &             (TOTFTP(P,2)+TOTFTP(P,3)+TOTFTP(P,4)) / NUMFLD
5     CONTINUE
C     Perform maintenance on failed cars.
        DO 11 P=1,2
          FFA(P) = 0
          FFPR(P) = 0
          IF( NUMFLD .EQ. 0) GOTO 14
          DO 11 COPASS=1,2
            DO 11 HCPASS=1,2
      IF( HCPASS.EQ.1 .AND. COPASS.EQ.1 ) GO TO 11
C
      AMFTP(HCPASS,COPASS,P,WITH)=0.0
      IF(NF(GRP(HCPASS,COPASS)) .EQ. 0) GO TO 11
      DO 12 IP=1,2
```

```
   12 IREG(IP)=AMIN1(CUTPTS(IP,TECH,AGE1ST,ISTRIN),
     &           A(IP,1,TECH)
     &          +A(IP,2,TECH)*AVGMIL(GRP(HCPASS,COPASS))
     &          +A(IP,3,TECH)*CUTPTS(2,TECH,AGE1ST,ISTRIN))
C
      AMFTP(HCPASS,COPASS,P,WTHOUT)= K(HCPASS,COPASS,P,TECH) *
     &         ( C(HCPASS,COPASS,P,TECH,1)
     &          +C(HCPASS,COPASS,P,TECH,2)*AVGMIL(GRP(HCPASS,COPASS))
     &          +C(HCPASS,COPASS,P,TECH,3)*IREG(1)
     &          +C(HCPASS,COPASS,P,TECH,4)*IREG(2))
C
      AMFTP(HCPASS,COPASS,P,WITH)=AMIN1(AMFTP(HCPASS,COPASS,P,WTHOUT),
     &     DPRIME(HCPASS,COPASS,P,TECH)
     &     +D(HCPASS,COPASS,P,TECH)*AVGMIL(GRP(HCPASS,COPASS)))
C
C     Calculate after maintenace FTP. If there is no mechanic training,
C     then we will just take the 'without' value. If there is a training
C     program, then calculate after maintenance emissions with & withoug
C     mechanic training and apply the mechanic training percentages to
C     the difference
           AMFTP(HCPASS,COPASS,P,WITH)=AMFTP(HCPASS,COPASS,P,WTHOUT)
     &     -(AMFTP(HCPASS,COPASS,P,WTHOUT)-AMFTP(HCPASS,COPASS,P,WITH))
     &     * MTP(BY)
C
        AMFTP(HCPASS, COPASS, P, WITH) = AMIN1(
     *    (TOTFTP(P,GRP(HCPASS, COPASS)) / NF(GRP(HCPASS, COPASS))),
     *    AMFTP(HCPASS, COPASS, P, WITH)      )
C
11     CONTINUE
C
   14 CONTINUE
C
C     Calculate Failed Fleet After maintenace emissions, a composite.
C
      DO 20 P=1,2
      IF(NUMFLD.LE.0) GO TO 15
        FFA(P) = (AMFTP(1,2,P,WITH) * NF(GRP(1,2))+
     &  AMFTP(2,1,P,WITH) * NF(GRP(2,1))+
     &  AMFTP(2,2,P,WITH) * NF(GRP(2,2))) / NUMFLD
      FFPR(P)= ( FFB(P)-FFA(P) ) / FFB(P) *100.0 + .5
 15   TFA(AGE,P)=( PF(P)*NF(1) + FFA(P)*NUMFLD )/ (NF(1)+NUMFLD)
      TFPR(P)= ( TFB(AGE,P)-TFA(AGE,P) ) / TFB(AGE,P) *100.0 + .5
20    CONTINUE
C
C
C
C     LAST STEP
C     WRITE OUT INFORMATION IN TABLE 1
      IF(.NOT.TABLES) GO TO 99
      IMTP=MTP(AGE)*100.+.5
        WRITE(1,101)AGE,MILES(AGE),(MOBFTP(AGE,P,TECH),P=1,2)
     & ,(TFB(AGE,P),P=1,2),(TFA(AGE,P),P=1,2),(TFPR(P),P=1,2)
     & ,(PF(P),P=1,2),(FFB(P),P=1,2),(FFA(P),P=1,2),(FFPR(P),P=1,2)
     & ,IMTP,(CUTPTS(P,TECH,AGE1ST,ISTRIN),P=1,2)
```

```
C
C
 101  FORMAT(I4,F7.1,2(3(F7.2,F6.1),I5,I4,2X),I6,F8.0,F5.1)
C
   99 RETURN
      END
```

```
      SUBROUTINE DTRATN(AGE)
C
C     THE 'MOB' COMMON BLOCK CONTAINS THE MOBILE2 ESTIMATES
C     OF MILEAGE AND FTP EMISSION LEVELS
C     FOR EACH TECHNOLOGY BY AGE OF VEHICLE
C
C     THESE VARIBALES ARE ALL INITIALIZED IN A BLOCK DATA STATEMENT
C
C     VARIABLE                  DESCRIPTION
C     MILES(AGE)                ESTIMATED MILEAGE AT AGE 'AGE'
C     MOBFTP(AGE,P,TECH)        ESTIMATED FTP LEVEL AT AGE 'AGE',
C                               TECHNOLOGY 'TECH' AND POLLUTANT 'P'
C     JMILES(AGE)               MILEAGE ON JAN 1 CY, WHERE AGE=CY-MY
C     JFTP(AGE,P,TECH)          NON I/M FLEET FTP ON JAN 1
C     INT(P,TECH)               MOBILE2 INTERCEPTS
C     SLOPE(P,TECH)             MOBILE2 SLOPES FOR EMISSIONS
C     STND(P,TECH)              FTP STANDARDS
C
      COMMON /MOB/ MILES, MOBFTP, JMILES, JFTP, INT, SLOPE, STND
      REAL*4 MILES(20), MOBFTP(20,2,2), JMILES(20), JFTP(20,2,2),
     1       INT(2,2), SLOPE(2,2), STND(2,2)
C
C     THE 'BKGRND' COMMON BLOCK CONTAINS BACKGROUND INFORMATION
C     NEEDED TO DEFINE THE I/M PROGRAM
C
C     VARIABLE          DESCRIPTION
C     TECH              TECHNOLOGY NUMBER
C     AGE1ST            AGE OF VEHICLES AT FIRST INSPECTION
C     MTP(BY)           MECHANIC TRAINING PERCENT AT BENEFIT YEAR 'BY'
C     CUTPTS(BY,P)      IDLE CUTPOINTS AT BENEFIT YEAR 'BY'
C                       FOR POLLUTANT 'P'
C     ESTSF             ESTIMATED STRINGENCY FACTOR
C     TABLES            LOGICAL VARIABLE TO SUPRESS OUTPUT OF TABLES
C
      COMMON/BKGRND/TECH,AGE1ST,MTP,CUTPTS,ESTSF,TABLES
      INTEGER*4 TECH,AGE1ST,ESTSF
      REAL*4    CUTPTS(2,2,19,5),MTP(20)
      LOGICAL TABLES
C     'MEANS' COMMON BLOCK CONTAINS MEAN MILEAGE,FTPHC ,FTPCO
C     WE HAVE TO MAKE OUR SAMPLE AGREE WITH THESE MEANS
C
C     VARIABLE              DESCRIPTION
C     MODOM                 MEAN ODOMETER
C     MFTP(P)               MEAN FTP FOR POLLUTANT 'P'
C
      COMMON/MEANS/MODOM,MFTP
      REAL*4 MODOM,MFTP(2)
C
C     'HSTRY' COMMON BLOCK CONTAINS EMISSION HISTORY THROUGHOUT PROGRAM
C
C     VARIABLE                  DESCRIPTION
C     TFB(AGE,P)                TOTAL FLEET FTP BEFORE INSPECTION
C     TFA(AGE,P)                TOTAL FLEET FTP AFTER INSPECTION
```

```
C     F                          F=1 PASSED THE TEST
C                                 =2 FAILED FOR HC ONLY
C                                 =3 FAILED FOR CO ONLY
C                                 =4 FAILED FOR BOTH
C     NF(F)                      NUMBER IN EACH GROUP
C     TOTFTP(P,F)                TOTAL FTP IN EACH GROUP
C     PR(P,BY)                   PERCENT REDUCTION ON JANUARY 1ST
C     AVGMIL(F)                  AVERAGE MILEAGE FOR FAILURE GROUP
C
      COMMON/HSTRY/ TFB,TFA,NF,TOTFTP,AVGMIL,PR
      REAL*4 TFB(20,2),TFA(20,2),TOTFTP(2,4),AVGMIL(4)
      INTEGER*4 NF(4),PR(2,20)
C
C     AFTER A YEAR ON THE ROAD, MILAGE IS EXPECTED TO INCREASE BY
C     'MILE'. PROJECTED MILEAGE IS MILES(AGE) + MILE. PLUG THIS
C     INTO THE MOBILE 2 EQUATION TO DETERMINE THE PROJECTED
C     EMISSIONS
C
      INTEGER AGE, P
      REAL PROJY(2), PROJX(2)
      REAL MILE(2,2)/.74, 4.0, 2.70, 5.72/
      DO 5 P=1,2
        PROJX(P) = MILES(AGE) + MILE(P,TECH)
        PROJY(P) = PROJX(P) * SLOPE(P, TECH) + INT(P, TECH)
5     CONTINUE
C
C     USING THE AFTER MAINTENANCE MEAN FTP EMISSIONS AT THE
C     PROJECTED MILEAGE, AND THE EMISSIONS AFTER ONE YEAR AS
C     PREDICTED BY MOBILE 2 EQUATIONS (CALCULATED ABOVE),
C     COMPUTE THE EQUATION OF 'ACTUAL' DETERIORATION AND
C     DETERMINE WHAT THE EMISSIONS ARE AT THE NEXT MILEAGE
C     FROM THIS NEW EQUATION
C
C     RECALL
C     Y - Y1 = (Y2 - Y1/ X2 - X1)*( X - X1)
C     WHERE
C     Y2 = TFA(AGE,P)            Y1 = PROJY(P)
C     X2 = MILES(AGE)            X1 = PROJX(P)
C     X = MILES(AGE + 1)
C
      DO 10 P=1,2
        MFTP(P) = (TFA(AGE,P) - PROJY(P)) / (MILES(AGE) - PROJX(P))
     1 * (MILES( AGE + 1 ) -PROJX(P)) + PROJY(P)
        MFTP(P)=AMIN1(MFTP(P),MOBFTP(AGE+1,P,TECH))
      TFB(AGE+1,P)=MFTP(P)
10    CONTINUE
C
      MODOM = MILES( AGE + 1)
      RETURN
      END
```

```
      SUBROUTINE GETPR
C
C     THE 'BKGRND' COMMON BLOCK CONTAINS BACKGROUND INFORMATION
C     NEEDED TO DEFINE THE I/M PROGRAM
C
C     VARIABLE          DESCRIPTION
C     TECH              TECHNOLOGY NUMBER
C     AGE1ST            AGE OF VEHICLES AT FIRST INSPECTION
C     MTP(BY)           MECHANIC TRAINING PERCENT AT BENEFIT YEAR 'BY'
C     CUTPTS(BY,P)      IDLE CUTPOINTS AT BENEFIT YEAR 'BY'
C                       FOR POLLUTANT 'P'
C     ESTSF             ESTIMATED STRINGENCY FACTOR
C     TABLES            LOGICAL VARIABLE TO SUPRESS OUTPUT OF TABLES
C
      COMMON/BKGRND/TECH,AGE1ST,MTP,CUTPTS,ESTSF,TABLES
      INTEGER*4 TECH,AGE1ST,ESTSF
      REAL*4    CUTPTS(2,2,19,5),MTP(20)
      LOGICAL TABLES
C
C     THE 'MOB' COMMON BLOCK CONTAINS THE MOBILE2 ESTIMATES
C     OF MILEAGE AND FTP EMISSION LEVELS
C     FOR EACH TECHNOLOGY BY AGE OF VEHICLE
C
C     THESE VARIBALES ARE ALL INITIALIZED IN A BLOCK DATA STATEMENT
C
C     VARIABLE                  DESCRIPTION
C     MILES(AGE)                ESTIMATED MILEAGE AT AGE 'AGE'
C     MOBFTP(AGE,P,TECH)        ESTIMATED FTP LEVEL AT AGE 'AGE',
C                               TECHNOLOGY 'TECH' AND POLLUTANT 'P'
C     JMILES(AGE)               MILEAGE ON JAN 1 CY, WHERE AGE=CY-MY
C     JFTP(AGE,P,TECH)          NON I/M FLEET FTP ON JAN 1
C     INT(P,TECH)               MOBILE2 INTERCEPTS
C     SLOPE(P,TECH)             MOBILE2 SLOPES FOR EMISSIONS
C     STND(P,TECH)              FTP STANDARDS
C
      COMMON /MOB/ MILES, MOBFTP, JMILES, JFTP, INT, SLOPE, STND
      REAL*4 MILES(20), MOBFTP(20,2,2), JMILES(20), JFTP(20,2,2),
     1       INT(2,2), SLOPE(2,2), STND(2,2)
C
C     'HSTRY' COMMON BLOCK CONTAINS EMISSION HISTORY THROUGHOUT PROGRAM
C
C     VARIABLE                  DESCRIPTION
C     TFB(AGE,P)                TOTAL FLEET FTP BEFORE INSPECTION
C     TFA(AGE,P)                TOTAL FLEET FTP AFTER INSPECTION
C     F                         F=1 PASSED THE TEST
C                                =2 FAILED FOR HC ONLY
C                                =3 FAILED FOR CO ONLY
C                                =4 FAILED FOR BOTH
C     NF(F)                     NUMBER IN EACH GROUP
C     TOTFTP(P,F)               TOTAL FTP IN EACH GROUP
C     PR(P,BY)                  PERCENT REDUCTION ON JANUARY 1ST
C     AVGMIL(F)                 AVERAGE MILEAGE FOR FAILURE GROUP
```

```
C
      COMMON/HSTRY/ TFB,TFA,NF,TOTFTP,AVGMIL,PR
      REAL*4 TFB(20,2),TFA(20,2),TOTFTP(2,4),AVGMIL(4)
      INTEGER*4 NF(4),PR(2,20)
C     'MEANS' COMMON BLOCK CONTAINS MEAN MILEAGE,FTPHC ,FTPCO
C     WE HAVE TO MAKE OUR SAMPLE AGREE WITH THESE MEANS
C
C     VARIABLE              DESCRIPTION
C     MODOM                 MEAN ODOMETER
C     MFTP(P)               MEAN FTP FOR POLLUTANT 'P'
C
      COMMON/MEANS/MODOM,MFTP
      REAL*4 MODOM,MFTP(2)
C
C     THIS SUBROUTINE CALCULATES THE AVERAGE FLEET EMISSIONS
C     ON JAN 1 FOR EACH CALENDER YEAR STARTING MY+1
C
C
C
C      THE 'TFL' COMMON BLOCK HOLDS BEFORE AND AFTER
C      FLEET MEAN EMISSIONS FROM THE LAST AGE1ST
C      TFAL(BY,P) = TFA(BY,P) FROM THE LAST TIME
C      TFBL(BY,P) = TFB(BY,P) FROM THE LAST TIME
C          THESE VARIABLES ARE ONLY "COMMON" TO THIS SUBROUTINE |
C
      COMMON/TFL/TFAL,TFBL
      REAL TFAL(20,2),TFBL(20,2)
C
      INTEGER EVAL,AGE,P,BY
      REAL EMIS(2,20)
C
C     VARIABLE       DESCRIPTION
C     EMIS(P,BY)   I/M EMISSIONS ON JAN 1ST
C
      LAST= 20 - AGE1ST
C
C
C     STEP 1
C     CALCULATE EMISSIONS OF THE I/M FLEET ON JAN1
      IF(AGE1ST .GT. 1) GO TO 11
      DO 10 P=1,2
        EMIS(P,1) = .75*(.375*INT(P,TECH) + .625*MOBFTP(1,P,TECH))
     +            + .25*(.875*TFA(1,P) + .125*TFB(2,P))
      DO 10 BY=2,19
       AGE=BY
        EMIS(P,BY) = .75*(.375*TFA(AGE-1,P) + .625*TFB(AGE,P))
     +             + .25*(.875*TFA(AGE,P) + .125*TFB(AGE+1,P))
   10 CONTINUE
      GO TO 13
   11 CONTINUE
      DO 12 BY=1,LAST
        AGE=BY+AGE1ST-1
```

```
      DO 12 P=1,2
        EMIS(P,BY) = .75*(.375*TFAL(AGE-1,P) + .625*TFBL(AGE,P))
     +             + .25*(.875*TFA(AGE,P) + .125*TFB(AGE+1,P))
   12 CONTINUE
   13 CONTINUE
C
C     STEP 2
C     CALCULATE PERCENT REDUCTIONS ON JAN1
      DO 20 P=1,2
      DO 20 BY=1,LAST
      AGE=AGE1ST+BY-1
        PR(P,BY)=(JFTP(AGE+1,P,TECH)-EMIS(P,BY))
     &       / JFTP(AGE+1,P,TECH) *100. +.5
      TFAL(AGE,P)=TFA(AGE,P)
      TFBL(AGE,P)=TFB(AGE,P)
 20   CONTINUE
C
C     STEP 3
      IF (.NOT.TABLES) GO TO 99
C
C     WRITE OUT THE RESULTS ON TABLE 3
      DO 30 BY=1,LAST
      AGE=AGE1ST+BY-1
      IMTP=MTP(AGE)*100.+.5
        WRITE(3,301)AGE,JMILES(AGE+1),(JFTP(AGE+1,P,TECH),P=1,2),
     &       (EMIS(P,BY),P=1,2),(PR(P,BY),P=1,2),IMTP
 30   CONTINUE
C
 301  FORMAT(T26,I2,T33,F5.1,T44,F5.2,T51,F5.1,T64,F5.2,
     &  T71,F5.1,T82,I3,T89,I3,T99,I6)
C
 99   RETURN
      END
```

```
      FUNCTION AVER(N,ARRAY)
C
      REAL ARRAY(2678)
      INTEGER N
C
      SUM=0
      DO 5 I=1,N
 5    SUM=SUM+ARRAY(I)
C
      AVER=SUM/N
      RETURN
      END
```

```
      BLOCK DATA
C
COMMON/MOB/MILES,MFTP1,MFTP2,JMILES,JFTP1,JFTP2,INT1,INT2,SLOPE1,SLOPE2,STND
C
      REAL MILES(20),MFTP1(20,2),MFTP2(20,2)
      REAL JMILES(20),JFTP1(20,2),JFTP2(20,2)
      REAL INT1(2),INT2(2),SLOPE1(2),SLOPE2(2),STND(2,2)
C
C     STANDARDS ARE NOT REALLY RIGHT
C     WE ARE USING STANDARDS FOR 68-74 FOR TECH 1,
C     AND IGNORING PRE 68'S
      DATA STND/3.05,34.05,1.55,15.05/
      DATA MILES/
C     MILES BY AGE
     & 1.440,  2.830,  4.170,  5.460,  6.690,  7.870,  8.990, 10.060,
     & 11.080, 12.040, 12.950, 13.810, 14.610, 15.360, 16.060, 16.700,
     & 17.290, 17.830, 18.320, 18.750/
      DATA JMILES/
C     AVERAGE FLEET MILEAGE ON JAN 1
     & 0.180,  1.078,  2.481,  3.833,  5.136,  6.381,  7.573,  8.708,
     & 9.791, 10.823, 11.798, 12.721, 13.593, 14.408, 15.171, 15.883,
     & 16.538, 17.141, 17.693, 18.196 /
      DATA MFTP2/
C     FTP HC BY AGE
     & 1.51,  1.91,  2.30,  2.67,  3.03,  3.37,  3.70,  4.01,  4.30,
     & 4.58,  4.85,  5.09,  5.33,  5.54,  5.75,  5.93,  6.10,  6.26,
     & 6.40,  6.53,
C     FTP CO BY AGE
     & 22.15, 26.12, 29.96, 33.65, 37.16, 40.54, 43.74, 46.80, 49.72,
     & 52.46, 55.07, 57.53, 59.81, 61.96, 63.96, 65.79, 67.48, 69.02,
     & 70.43, 71.65/
      DATA JFTP2/
C     AVERAGE FLEET FTP HC ON JAN 1
     & 1.14,  1.40,  1.81,  2.20,  2.58,  2.94,  3.29,  3.62,  3.93,
     & 4.23,  4.51,  4.78,  5.03,  5.27,  5.49,  5.70,  5.89,  6.06,
     & 6.22,  6.37,
C     AVERAGE FLEET FTP CO ON JAN 1
     & 18.54, 21.11, 25.13, 28.99, 32.72, 36.28, 39.69, 42.94, 46.03,
     & 48.98, 51.77, 54.41, 56.91, 59.24, 61.42, 63.46, 65.33, 67.05,
     & 68.63, 70.07 /
C
      DATA MFTP1/
C     FTP HC BY AGE
     & 3.60,  3.84,  4.07,  4.29,  4.50,  4.70,  4.89,  5.07,  5.24,
     & 5.41,  5.56,  5.71,  5.84,  5.97,  6.09,  6.20,  6.30,  6.39,
     & 6.47,  6.55,
C     FTP CO BY AGE
     & 44.29, 47.69, 50.95, 54.10, 57.10, 59.98, 62.72, 65.33, 67.82,
     & 70.16, 72.38, 74.48, 76.43, 78.26, 79.97, 81.53, 82.97, 84.29,
     & 85.48, 86.53/
      DATA JFTP1/
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C      AVERAGE FLEET FTP HC ON JAN 1
     & 3.39, 3.54, 3.78, 4.01, 4.23, 4.44, 4.65, 4.84, 5.02,
     & 5.20, 5.37, 5.52, 5.67, 5.81, 5.94, 6.06, 6.17, 6.27,
     & 6.37, 6.45,
C      AVERAGE FLEET FTP CO ON JAN 1
     & 41.22, 43.41, 46.83, 50.13, 53.31, 56.35, 59.26, 62.03, 64.67,
     & 67.19, 69.57, 71.82, 73.95, 75.94, 77.80, 79.53, 81.13, 82.60,
     & 83.95, 85.18 /
      DATA INT1/3.36, 40.78/
      DATA SLOPE1/.17, 2.44/
      DATA INT2/1.09,18.03/
      DATA SLOPE2/.29,2.86/
      END
      BLOCK DATA
      COMMON/BKGRND/TECH,AGE1ST,MTP,
     *CUTPT1,CUTPT2,CUTPT3,CUTPT4,CUTPT5,ESTSF,TABLES
      INTEGER*4 TECH,AGE1ST,ESTSF
      REAL*4 CUTPT1(2,2,19),CUTPT2(2,2,19),CUTPT3(2,2,19),
     *CUTPT4(2,2,19),CUTPT5(2,2,19),MTP(20)
      LOGICAL TABLES
      DATA CUTPT1/                801.6, 8.02, 590.3, 5.90,
     * 854.3, 8.54, 708.1, 7.08, 903.7, 9.04, 824.5, 8.24,
     * 951.5, 9.51, 935.3, 9.35,1004.0,10.04,1038.8,10.39,
     *1054.4,10.54,1139.9,11.40,1104.4,11.04,1232.6,12.33,
     *1148.8,11.49,1316.9,13.17,1193.0,11.93,1398.9,13.99,
     *1223.7,12.24,1477.6,14.78,1252.1,12.52,1563.1,15.63,
     *1287.8,12.88,1637.0,16.37,1319.3,13.19,1709.9,17.10,
     *1351.2,13.51,1772.2,17.72,1377.9,13.78,1830.6,18.31,
     *1406.5,14.07,1883.7,18.84,1424.5,14.24,1932.8,19.33,
     *1443.3,14.43,1977.8,19.78,1463.0,14.63,2024.0,20.24/
      DATA CUTPT2/                584.5, 5.85, 388.1, 3.88,
     * 624.3, 6.24, 468.4, 4.68, 661.7, 6.62, 545.8, 5.46,
     * 697.2, 6.97, 617.4, 6.17, 729.6, 7.30, 689.5, 6.89,
     * 763.8, 7.64, 758.9, 7.59, 793.9, 7.94, 822.1, 8.22,
     * 824.2, 8.24, 883.4, 8.83, 854.7, 8.55, 939.9, 9.40,
     * 882.6, 8.83, 993.1, 9.93, 912.0, 9.12,1043.8,10.44,
     * 938.5, 9.38,1091.4,10.91, 963.6, 9.64,1135.7,11.36,
     * 983.5, 9.83,1179.4,11.79,1005.7,10.06,1216.4,12.16,
     *1025.7,10.26,1251.6,12.52,1044.8,10.45,1290.5,12.90,
     *1059.0,10.59,1318.5,13.18,1071.2,10.71,1343.9,13.44/
      DATA CUTPT3/                478.1, 4.78, 272.2, 2.44,
     * 513.1, 5.13, 303.9, 3.04, 543.8, 5.44, 350.5, 3.50,
     * 575.4, 5.75, 398.1, 3.98, 604.5, 6.04, 440.2, 4.40,
     * 631.3, 6.31, 483.5, 4.84, 655.4, 6.55, 523.2, 5.23,
     * 679.3, 6.79, 562.9, 5.63, 703.3, 7.03, 599.0, 5.99,
     * 725.7, 7.26, 636.0, 6.36, 748.1, 7.48, 669.3, 6.69,
     * 767.1, 7.67, 700.6, 7.01, 786.9, 7.87, 728.8, 7.29,
     * 804.1, 8.04, 755.8, 7.56, 820.4, 8.20, 783.3, 7.83,
     * 834.1, 8.34, 804.1, 8.04, 847.6, 8.48, 825.3, 8.25,
     * 859.3, 8.59, 851.2, 8.51, 870.0, 8.70, 868.0, 8.68/
      DATA CUTPT4/                395.2, 3.95, 209.7, 1.19,
     * 423.4, 4.23, 227.2, 1.54, 449.6, 4.50, 247.6, 1.95,
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* 475.5, 4.75, 266.8, 2.33, 501.3, 5.01, 284.1, 2.68,
* 522.9, 5.23, 304.7, 3.05, 543.6, 5.44, 331.2, 3.31,
* 564.7, 5.65, 355.6, 3.56, 584.4, 5.84, 379.4, 3.79,
* 602.4, 6.02, 395.5, 3.96, 621.1, 6.21, 419.1, 4.19,
* 640.6, 6.41, 437.3, 4.37, 657.1, 6.57, 454.3, 4.54,
* 673.4, 6.73, 470.2, 4.70, 686.9, 6.87, 489.2, 4.89,
* 699.5, 7.00, 502.8, 5.03, 710.6, 7.11, 515.4, 5.15,
* 720.3, 7.20, 526.9, 5.27, 729.5, 7.29, 537.4, 5.37/
 DATA CUTPT5/
                              316.1, 3.16, 174.9, 0.49,
* 336.4, 3.36, 180.7, 0.61, 355.6, 3.56, 188.1, 0.76,
* 378.0, 3.78, 196.8, 0.93, 398.1, 3.98, 206.2, 1.12,
* 417.5, 4.17, 213.5, 1.26, 434.7, 4.35, 221.3, 1.42,
* 450.0, 4.50, 230.3, 1.60, 464.9, 4.65, 240.7, 1.81,
* 479.3, 4.79, 248.0, 1.95, 494.0, 4.94, 255.9, 2.11,
* 507.4, 5.07, 265.6, 2.31, 518.2, 5.18, 274.7, 2.49,
* 529.2, 5.29, 282.5, 2.64, 540.5, 5.40, 290.9, 2.81,
* 550.3, 5.50, 299.3, 2.98, 559.3, 5.59, 306.4, 3.06,
* 567.7, 5.68, 313.5, 3.13, 575.4, 5.75, 321.5, 3.22/
 END
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      SUBROUTINE MATRIX(MT,ISTRIN,ITECH)
C
C
C     'HSTRY' COMMON BLOCK CONTAINS EMISSION HISTORY THROUGHOUT PROGRAM
C
C     VARIABLE                    DESCRIPTION
C     TFB(AGE,P)                  TOTAL FLEET FTP BEFORE INSPECTION
C     TFA(AGE,P)                  TOTAL FLEET FTP AFTER INSPECTION
C     F                           F=1 PASSED THE TEST
C                                  =2 FAILED FOR HC ONLY
C                                  =3 FAILED FOR CO ONLY
C                                  =4 FAILED FOR BOTH
C     NF(F)                       NUMBER IN EACH GROUP
C     TOTFTP(P,F)                 TOTAL FTP IN EACH GROUP
C     PR(P,BY)                    PERCENT REDUCTION ON JANUARY 1ST
C     AVGMIL(F)                   AVERAGE MILEAGE FOR FAILURE GROUP
C
      COMMON/HSTRY/ TFB,TFA,NF,TOTFTP,AVGMIL,PR
      REAL*4 TFB(20,2),TFA(20,2),TOTFTP(2,4),AVGMIL(4)
      INTEGER*4 NF(4),PR(2,20)
C
C     THE 'BKGRND' COMMON BLOCK CONTAINS BACKGROUND INFORMATION
C     NEEDED TO DEFINE THE I/M PROGRAM
C
C     VARIABLE          DESCRIPTION
C     TECH              TECHNOLOGY NUMBER
C     AGE1ST            AGE OF VEHICLES AT FIRST INSPECTION
C     MTP(BY)           MECHANIC TRAINING PERCENT AT BENEFIT YEAR 'BY'
C     CUTPTS(BY,P)      IDLE CUTPOINTS AT BENEFIT YEAR 'BY'
C                       FOR POLLUTANT 'P'
C     ESTSF             ESTIMATED STRINGENCY FACTOR
C     TABLES            LOGICAL VARIABLE TO SUPRESS OUTPUT OF TABLES
C
      COMMON/BKGRND/TECH,AGE1ST,MTP,CUTPTS,ESTSF,TABLES
      INTEGER*4 TECH,AGE1ST,ESTSF
      REAL*4    CUTPTS(2,2,19,5),MTP(20)
      LOGICAL TABLES
C
      INTEGER BY,BYLAST,P,RED(19,20,5,2,2)
C
C      THIS SUBROUTINE FORMS THE JANUARY 1 EMISSION REDUCTION
C      MATRIX FOR MOBILE2.
C      SINCE THE REDUCTIONS FORM A TRIANGULAR MATRIX, HALF OF IT
C      IS STORED IN REVERSE ORDER IN THE LOWER HALF OF THE ARRAY
C      TO SAVE SPACE.
C
C      STEP 1
C      STORE THE CURRENT JANUARY REDUCTIONS IN THE REDUCTION
C      MATRIX.  IF THERE IS MECHANICS TRAINING, (MT=2), STORE
C      THE REDUCTIONS IN THE LOWER HALF OF THE ARRAY.
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C
      BYLAST=20-AGE1ST
      IF(MT.EQ.2) GO TO 30
C
      DO 20 P=1,2
        DO 20 BY=1,BYLAST
 20       RED(BY,AGE1ST,ISTRIN,ITECH,P)=PR(P,BY)
      GO TO 40
C
 30   DO 35 P=1,2
        DO 35 BY=1,BYLAST
 35       RED(20-BY,21-AGE1ST,ISTRIN,ITECH,P)=PR(P,BY)
C
C      STEP 2
C      IF THE I/M SEQUENCE IS COMPLETE, WRITE OUT THE MATRIX IN THE
C      FORM OF 20 DATA BLOCKS FOR USE BY MOBILE2.
C
 40   IF(.NOT.((ITECH.EQ.2).AND.(ISTRIN.EQ.5)
     &    .AND.(MT.EQ.2).AND.(AGE1ST.EQ.19))) GO TO 99
C
      WRITE(5,100)
 100  FORMAT('C      INSPECTION/MAINTENANCE PERCENT REDUCTIONS:')
C
      ICOUNT=1
C
      DO 90 P=1,2
        DO 90 ITECH=1,2
          DO 90 ISTRIN=1,5
C
            IF(ICOUNT.LT.10) WRITE(5,150) ICOUNT,
     &         (RED(BY,1,ISTRIN,ITECH,P),BY=1,19)
            IF(ICOUNT.GE.10) WRITE(5,160) ICOUNT,
     &         (RED(BY,1,ISTRIN,ITECH,P),BY=1,19)
 150        FORMAT(6X,'DATA R',I1,'/',19(I2,','))
 160        FORMAT(6X,'DATA R',I2,'/',19(I2,','))
            ICOUNT=ICOUNT+1
C
            DO 60 AGE1ST=2,19
 60         WRITE(5,200)(RED(BY,AGE1ST,ISTRIN,ITECH,P), BY=1,19)
 200        FORMAT(5X,'*',8X,19(I2,','))
C
            WRITE(5,250)(RED(BY,20,ISTRIN,ITECH,P), BY=1,19)
 250        FORMAT(5X,'*',8X,18(I2,','),I2,'/')
C
 90   CONTINUE
C
 99   RETURN
      END
```